Fall 2014

A multilevel analysis of project lead the way implementation in Indiana

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Graduate School Form 30
(Revised 08/14)

PURDUE UNIVERSITY
GRADUATE SCHOOL
Thesis/Dissertation Acceptance

This is to certify that the thesis/dissertation prepared

By Brandon Herald Sorge

Entitled
A MULTI-LEVEL ANALYSIS OF PROJECT LEAD THE WAY IMPLEMENTATION IN INDIANA

For the degree of Doctor of Philosophy

Is approved by the final examining committee:

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Approved by: James L. Mohler 12/02/2014

Head of the Department Graduate Program Date

A MULTILEVEL ANALYSIS OF PROJECT LEAD THE WAY IMPLEMENTATION IN INDIANA

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Brandon H. Sorge

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

December 2014

Purdue University

West Lafayette, Indiana

For my family

ACKNOWLEDGEMENTS

This dissertation, like everything I have done in my life, happened because of the people in my life.

I owe an incredible amount of gratitude to Melissa Dark for her patience and guidance over a much longer period of time than either of us expected. Additionally, a great deal of thanks goes to Charlie Feldhaus for his role as a friend, associate, and mentor. I also greatly appreciate the contributions and guidance from my committee members Jenny Daugherty and John Staver.

To my family and friends, thank you so much for your support in my life.

Little Miss, thank you for making every day brighter.

Devon, my wife, thank you for being my partner in the adventure called life. It has been a much richer experience because of you.

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LIST OF ABBREVIATIONS

Analysis of variances (ANOVA)

Elementary and Secondary Education Act (ESEA)

Hierarchical Linear Modeling (HLM)

High Schools that Work (HSTW)

Indiana Commission for Higher Education (ICHE)

Indiana Department of Education (IDOE)

The Indiana Department of Workforce Development (DWD)

Indiana Statewide Testing for Educational Progress Plus (ISTEP+)

Intraclass Correlation (ICC)

Institutional Analysis and Development (IAD)

Math Science Partnership (MSP)

Mid-continent Research for Education and Learning (McREL)

National Assessment for Educational Progress (NAEP)

National Science Foundation (NSF)

Pedagogical Content Knowledge (PCK)

Project Lead the Way (PLTW)

Science, Technology, Engineering, and Mathematics (STEM)

Trends in International Mathematics and Science Study (TIMSS)

United States (U.S.)

ABSTRACT

Sorge, Brandon H. Ph.D., Purdue University, December 2014. A Multilevel Analysis of Project Lead the Way Implementation in Indiana. Major Professor: Melissa Dark.

Using data from the 2010 Indiana public high school graduating class (N=55612), this project employed a multi-level analysis to determine, what if any differences occurred in majoring in STEM and freshman to sophomore year persistence, between students attending a school that offers Project Lead the Way and students that don't, while controlling for being a PLTW student. Additionally, this project explored the mitigating institutional factors that influenced a student majoring in STEM or persisting from their freshman to sophomore year in post-secondary education and if and how these factors varied depending upon if a student took PLTW courses, attended a PLTW school but did not take any PLTW courses, or attended a school that did not offer PLTW.

CHAPTER 1. INTRODUCTION

1.1 Introduction

There are many opinions about the number of current and future Science, Technology, Engineering, and Mathematic (STEM) job opportunities and the ability to fill those jobs in the United States (U.S.). Butz, Kelly, Adamson, Bloom, Sossum, and Gross (2004), before the recession, and Ruark and Graham (2011), during the start of the recovery, said that the supply of STEM workers was sufficient to meet the future demand. The United States Congress Joint Economic Committee (2012) claimed the opposite and said there was currently a shortage of STEM workers that would likely continue into the future. Carnevale, Smith, and Melton (2011) took a slightly different approach, claiming there was a shortage of STEM workers, not because universities weren't producing enough, but because STEM degree holders were self-selecting to work in other fields. No matter who is correct, the economic impact from a strong STEM workforce is not in question.

Rothwell (2014) found that the median duration of STEM vacancy postings is more than twice that of non-STEM vacancies. From associate degrees to PhDs, STEM positions and positions requiring STEM skills take longer to fill. In Indiana, the demand for STEM workers is apparent and growing. The Hoosier Hot 50 Jobs is a listing of the fifty fastest growing, high wage jobs in Indiana. The economic strength of the state is dependent upon procuring workers for these high-demand, high-wage jobs. In the first Hoosier Hot 50 Job report of 2014, a strong STEM background was needed for each of the top five jobs: physician or surgeon; registered nurse; physical therapist; dental hygienist; and computer software engineer. Further, twenty-eight of the Hoosier Top 50 Jobs require high levels of knowledge in at least one STEM field (Indiana Department of Workforce Development, 2012). Additionally, Indiana, at 28.2%, has the highest percentage of gross state product attributed to manufacturing (Bureau of Economic Anlaysis, 2014). It is predicted that Indiana's STEM job growth will be consistent with the nation's STEM job growth, moreover Indiana computing job growth will outpace the national averages over the next 10 years (Rosen, 2014). Horn-Hann, Viswanathan, and Koh (2011) research showed that a STEM economy creates many other non-STEM jobs as well. Clearly, a knowledgeable and skilled STEM workforce is needed to maintain the economic growth of Indiana and the country. The development of this workforce resides within the education system, and the K-12 education system is the foundation of the pipeline.

Reports, such as *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academy of Science, 2006), have expressed that the scientific and technical building blocks critical for maintaining American economic leadership were eroding while other nations were gaining strength. In response to these reports, funding for STEM programming and program development was increased. In fiscal 2010, federal agencies invested in 209 STEM programs exceeding $3 billion (United States Government Accountability Office, 2012). Yet even with this extensive funding, results from the National Assessment for Educational

Progress (NAEP) and the Trends in International Mathematics and Science Study (TIMSS) show that, compared with their international counterparts, U.S. students made little to no gains in the STEM areas (Gonzales et al., 2008; National Center for Education Statistics, 2010a; Rampey, Dion, & Donahue, 2009).

With the apparent importance of STEM and STEM careers to the economy, the large amounts of money being spent on new programs and curricula, why aren't students in the U.S. performing better when compared to international peers? Why aren't students flocking to major in STEM disciplines and matriculate into the STEM workforce? Understanding these sorts of issues have been at the forefront of education research as well and education policy implementation research. Research on educational policy implementation has found that many education programs were having success and being implemented as desired. Where the problem lies is that there was still variation in how the same program was being implemented in different locations and in the outcomes being observed. Over the past 20 years, suggestions were made that policy implementation literature had not reached clarity (Ingram, 1990) and was at its intellectual end (deLeon, 1999; deLeon & deLeon, 2002). Therefore, alternative approaches were needed from other areas to further educational policy understanding (Fredrickson, 1999) especially since any given policy situation overlaps with many other policy situations, such that the activities of one situation affect others. This means no single discipline addresses all the human issues associated with complex social situations (Polski & Ostrom, 1999).

Implementation research depends heavily on institutional scholarship. Researchers have been strengthening the links between institutional theory and research in education policy and practice. The Institutional Analysis and Development framework (IAD) (Ostrom, 2011; Ostrom, Gardner, & Walker, 1999) has greatly reshaped policy research. IAD was developed as a general framework or multi-tiered conceptual map that allows for the integration of work from researchers involved in a wide range of disciplinary perspectives. IAD focuses on seven primary areas: Biophysical Conditions, Attributes of the Community, Rules-in-Use, Action Situations, Interactions, Evaluative Criteria, and Outcomes. It also provides researchers the ability to delve deeply into actions and their outcomes in complicated situations such as the selection and implementation of educational programs in the K-12 settings. IAD is an ideal framework to utilize in understanding the complex relationships between policies created to entice and enable schools to adopt certain STEM programs and observed outcomes. Specifically, to understand the institutional framework of schools and districts and their impact on student STEM outcomes is vital to help ensure that there is not a void of workers capable of filling the STEM jobs of the future.

Research on educational change has shown that several factors, e.g., teachers, principals, central office staff, and others, such as state departments of education, play important but different roles in school improvement and student performance (Crandall, 1983). The Mid-continent Research for Education and Learning (McREL) (2003) conducted a statistical analysis on a collection of individual studies. Using work done by Marzano (2003) on the school and teacher impacts on student achievement, McREL researchers found that student factors (home environment, learned intelligence/background knowledge, and motivation) account for approximately 80% of the variance in student achievement. Teacher-level factors (instructional strategies, classroom management, and classroom curriculum design) account for approximately 13% of student learning. School level factors (collegiality and professionalism, safe and orderly environment, a guaranteed and viable curriculum, challenging goals and effective feedback, and parent and community involvement) account for the final 7%. If teacher and school level factors account for 20% of the impact on student learning, why does the same curriculum fail in improving student performance at one school and succeed in another school with a similar student body? If student populations are similar, but a program fails in one place and not the other, institutional factors may play a major role in the success of program implementation.

Project Lead the Way (PLTW) provides rigorous, hands-on, project-based pre-engineering, science and, starting in 2014, computer science curriculum to help prepare the future STEM workforce. For the start of the 2014-2015 academic school year, PLTW was in over 6,500 schools offering 7,500 programs nationally (Project Lead the Way, 2014). Initial studies have shown that the PLTW curriculum has had success in increasing student performance and interest in STEM (Bottoms & Anthony, 2005; Laanan, Schenk, Starobin, Chapman, & Zhang, 2009; Pike & Robbins, 2014; Schenk et al., 2009; Van Overschelde, 2013). The PLTW *Pathway to Engineering* curriculum is a four-year high school sequence of courses that includes both foundation courses and elective courses. The PLTW Biomedical Science curriculum is a four-year high school sequence focused on the foundations of biomedical sciences (PLTW, 2010 website).

Indiana was an early adopter of PLTW. Beginning in 2005, Indiana's Department of Education and Department of Workforce Development implemented a funding policy to support implementation of PLTW in the state. This funding policy allocated money to schools to fund equipment, labs and software for PLTW programs as well as per student funding for each PLTW course completed. Funding was the same no matter school size, location, or financial status. The policy showed success in getting schools to adopt and, by 2010, approximately two-thirds of Indiana high schools offered PLTW courses, making Indiana the largest implementer of PLTW programs in the country.

1.2 Statement of the Problem

Institutional factors must interact with program level factors to create observed outcomes. However, often research does not provide specificity. It also doesn't take into account the interplay between the nested structure of school systems and how these different levels interact. For example, Indiana's education system is under local control. A local school district governs multiple schools in grades K-12. These schools, in turn, have multiple students. Schools within the same district have different leadership, student demographics, and locations, but they still are governed by the same district rules and leadership. Students within different schools often have different experiences because of school characteristics and leadership but will have similar experiences based upon being in the same district. Students are nested within schools, which are nested within districts, with each sitting on a level higher than the other, and each level interacting with the other.

PLTW in Indiana provides an excellent opportunity to research and investigate these interactions at multiple levels. As shown in Figure 1, there are two groups of students, those who have taken a PLTW course and those who have not. Each of these groups has outcomes related to building the STEM workforce of having students major in STEM and then persisting from their freshman to sophomore year of college. While getting more students to major in STEM is an important first step in increasing the pipeline, a significant percentage of students majoring in STEM fields drop out of school before the start of their sophomore year or switch to a non-STEM major (Thompson & Bolin, 2011), making persistence an important attribute to understand. Additionally, the work focused on achievement in K-12 and not on post-secondary major and persistence.

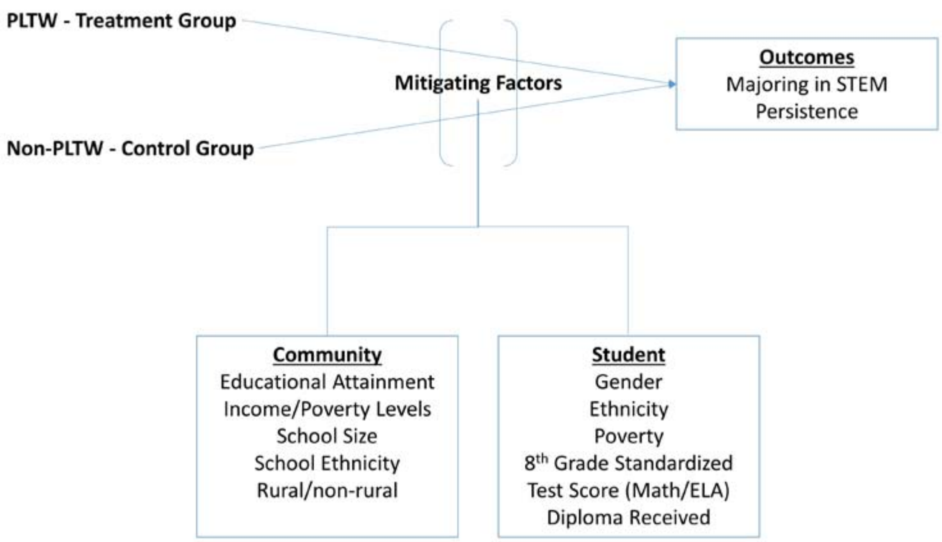

Figure 1.1 Model of Research

Figure 1.1 also lists mitigating factors that impact students from each of these groups and the likelihood they will major in STEM and/or persist. The research done by McREL (2003), focused on education as a whole and not on STEM. Do these same or similar factors play a role in majoring in STEM or persistence? Utilizing these factors in a three level nested model - using district/community, school, and student level factors (see Figure 1.2) will provide new insight on outcomes relevant to STEM. Understanding the roles these factors play in policy implementation can help policy makers craft better policies, which in turn create institutional factors needed for program success. This is especially important in how these factors affect students majoring in a STEM field as well as their persistence from their freshman to sophomore year in post-secondary education when so many students drop out in Indiana and across the country.

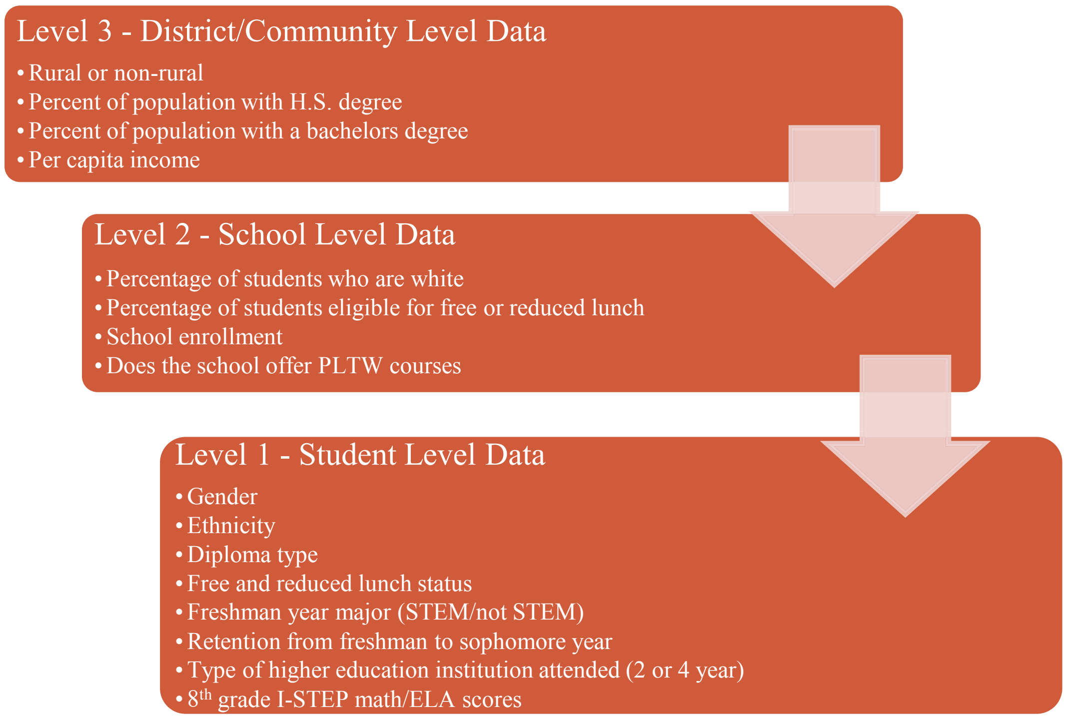

Figure 1.2 Nested Levels of Data

1.3 Research Questions

When looking at just the outcomes section of the model for research, see Figure 1.3, the following research questions were formulated related to the outcomes of a student having their post-secondary major be in STEM and for persisting from their freshman to sophomore year of college:

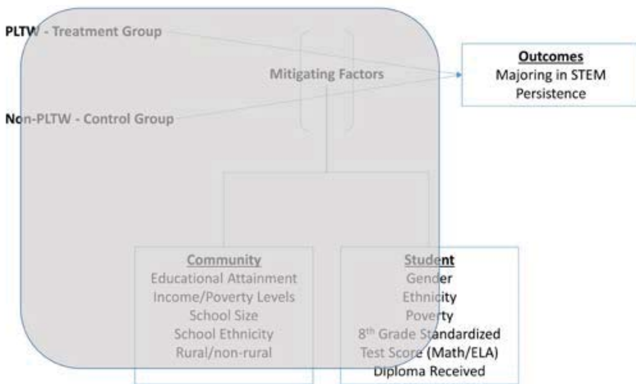

Figure 1.3 Outcomes

1. Does attending a school that offers PLTW increase the likelihood of students majoring in a post-secondary STEM program?
2. Does attending a school that offers PLTW increase the likelihood that a student will persist from their freshman to sophomore year of college?

Additionally, Figure 1.4 focuses on the mitigating factors involved within the diagram and is followed by research questions directly related to the mitigating factors:

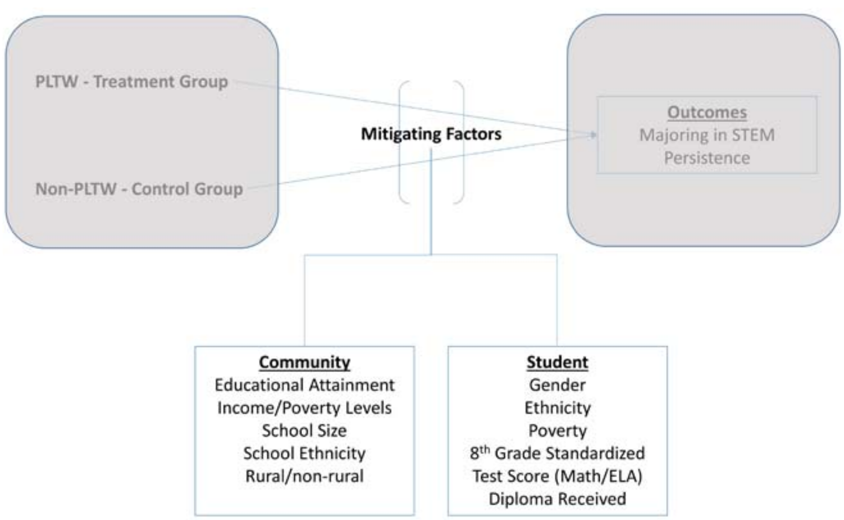

Figure 1.4 Mitigating Factors

3. Are the mitigating factors that are statistically significant for majoring in STEM different for PLTW schools and non-PLTW schools? Are these factors different for PLTW students?
4. Do district/community level factors that focus on educational attainment and income/wealth significantly impact the likelihood PLTW students major in STEM and does this differ for non-PLTW students at PLTW schools and students at non-PLTW schools?
5. For PLTW students, are the odds ratios for statistically significant district/community level factors greater than the odds ratio of school and student level variables for majoring in STEM and are these proportionally more than for non-PLTW students at PLTW schools and students at non-PLTW schools?
6. Are the mitigating factors that are statistically significant for persisting from the freshman to sophomore year of post-secondary education different for PLTW schools and non-PLTW schools? Are these factors different for PLTW students?
7. Are district/community level factors which focus on educational attainment and income/wealth statistically significant in impacting PLTW students persisting from their freshman to sophomore year of college and does this differ from the statistically significant factors for non-PLTW students at PLTW schools or students at non-PLTW schools for persisting?
8. For PLTW students, are the odds ratios for statistically significant district/community level factors greater than the odds ratio of school and student level variables for persisting from their freshman to sophomore year of college? Additionally, are the odds ratios for these factors proportionally greater for PLTW

students than non-PLTW students at PLTW schools and students at non-PLTW schools?

1.4 Significance of Problem

This study adds an important dimension to understanding the attributes of the community and how the variables involved mitigate student outcomes related to majoring in STEM and post-secondary persistence. This was done by comparing outcomes and how mitigating factors impact students involved in the treatment group, the control group, and if there is a whole school PLTW impact for control students attending a school with the treatment group. It did this by using other areas of research, specifically the IAD framework's attributes of the community, in a multi-level model, to allow for interplay between these factors and their nested structure.

Additionally, this study is significant because no PLTW study has examined why schools adopted the PLTW curriculum. Only two studies have included institutional factors. Nathan and Tran (2010) included teacher level of experience within their models, which can be a variable related to teacher hiring and retention practices at their institution. Rethwisch, Starobin, Laanan, and Haynes (2013) included the district as a random effect second level variable, but no other institutional factors at the school or district levels were included. This research provides insight to policy makers at all levels into factors that should be considered when creating policy that can impact a more diverse STEM workforce.

1.5 Statement of Purpose/Scope

The purpose of this research was to investigate if participation in a STEM program, such as PTLW leads, to differences in student outcomes when compared to non-program students and to identify differences in key institutional and mitigating factors that impact these outcomes. The scope of this project focused on the attributes of the communities in which public schools and their districts in Indiana reside. Specifically, this study focused on comparing PLTW schools to non-PLTW schools as well as comparing PLTW students, non-PLTW students at PLTW schools, and students at non-PLTW schools. This project identified how attributes of the community such as community levels of education, per capita income, median home value, percentage of the school that was non-white, and percentage of the school eligible for free and reduced lunch impact the implementation and outcome variation, depending upon association with a STEM program, specifically PLTW, through student level outcomes of persistence and post-secondary major.

1.6 Assumptions

There were several assumptions related to this research:

1. The data provided by the multiple agencies were accurate.
2. PLTW teachers at the participating schools participated in the appropriate PLTW professional development.
3. The participating PLTW schools participated in the funding policy by submitting a grant to the Indiana Department of Workforce Development and received initial funding to start their PLTW program.

4. The participating PLTW schools participated annually in the funding policy through submission and receipt of Perkins Grant funding for their students participating in PLTW courses.

1.7 Limitations

The data, while very extensive, relied upon having all post-secondary institutions with students from the 2010 Indiana graduating class report their data to the national clearing house. While it was assumed that this happened, in actuality, students listed as not having attended post-secondary education, may have indeed done so.

1.8 Delimitations

The study was delimited to data on the 2010 Indiana graduating class from non-charter public schools in the state of Indiana. This was done to ensure census data could be used to collect the district and community level data associated with each district. This is not possible to do with private or charter schools that take students outside of a defined boundary.

CHAPTER 2. REVIEW OF THE LITERATURE

Public policy research and STEM education policy have long, varied, and convoluted histories. Many national policies were created around STEM education, but none provided the intended overall impact. During this same time, education policy researchers have increased their efforts to understand the impacts of policies.

2.1 History of STEM Education Policy

Science, Technology, Engineering, and Mathematics have played significant roles in the history of the United States. The Morrill Act of 1862, originally established colleges and universities to study mechanical arts and agriculture but this legislation also supported science and engineering programs (Butz et al., 2004). More recently, the 1957 launch of the Soviet satellite, Sputnik, made legislative history, and still impacts the current view of America's ability to compete globally (Friedman, 2005). In reaction to the launch of Sputnik, Congress passed the National Defense of Education Act (P.L. 85-864) to create a strong American STEM workforce and to counteract what was deemed superior Soviet schools. This Act focused on training young scientists by increasing federal funding at all educational levels. The National Defense of Education Act was also designed as a catalyst to help the U.S. fight the economic competition of foreign powers (Passow, 1957).

2.1.1 Rising Above the Gathering Storm

Forty years after the launch of Sputnik, the U.S. found itself in a new call to better prepare a future STEM workforce. *Rising above the Gathering Storm, Energizing and Employing America for a Brighter Economic Future* (National Academy of Science, 2006) has been frequently cited by political and economic leaders as a prime example of findings that show the need of a stronger future STEM workforce. It expressed a deep concern that foundational scientific and technical building blocks for maintaining American economic leadership were eroding while other nations were gaining strength. Unlike the era of Sputnik, the U.S. was no longer competing with the Soviet Union, but instead was competing in a global marketplace (Dow, 1997). Moreover, the country had seen a decrease in the interest of its students in STEM careers. Also, STEM students who were inspired by the launch of Sputnik were approaching retirement age, and business and political leaders expressed concern about the country's ability to replace them (Friedman, 2005; Hyslop, 2010). The authoring committee believed that this erosion put the future economic prosperity of the United States at risk. They set forth five goals for improving STEM education:

1. Quadruple the number of middle and high school math and science courses being taken by 2010,
2. Annually recruit 10,000 new science and mathematics teachers,
3. Strengthen the science and mathematics skills of 250,000 current teachers,
4. Increase federal investment in research on graduate and early career STEM fields,
5. Increase the number and proportion of U.S. citizens earning a bachelor's degree in physical sciences, life science, engineering, and mathematics.

Increasing the number of science courses being taken at the middle and high school level was viewed as a way to increase the pipeline of future STEM degree recipients. To increase these numbers, the committee recommended dramatically increasing the number of students taking Advanced Placement and/or International Baccalaureate math and science courses from approximately 1.1 million students to 4.5 million students. The committee also suggested increasing the percentage of students passing the associated exams. It also recommended expansion of the number of STEM-focused high schools, the use of inquiry-based learning through experiences in laboratories, internships, and broader student research opportunities.

To recruit 10,000 new STEM teachers, a competitive grant program for merit-based scholarships was proposed. As part of this program teachers would obtain STEM area degrees along with certification as a mathematics or science teacher. It was recommended that to receive a grant, potential awardees must agree to five years of service in a school. Also, awardees could receive an additional $10,000 annually after graduation if they worked in a school with a large population of underserved students. To support this program, the committee recommended that matching grants be awarded to institutions of higher education to create programs that combine a STEM degree with a teacher certification.

The report recommended four strategies to build the skills of 250,000 current STEM teachers:

1. Create matching grants to establish state and regional summer programs for STEM teachers modeled after the Merck Institute for Science Education.

2. Provide additional support to institutions of higher education for supporting STEM advanced degree programs for current STEM teachers modeled after the University of Pennsylvania Science Teachers Institute.
3. Train current teachers to provide Advanced Placement and/or International Baccalaureate instruction modeled after the Advanced Placement Initiative.
4. Create a national panel charged with collecting, evaluating, and developing rigorous K-12 STEM curricula that is modeled after Project Lead the Way.

To increase graduate research in STEM areas, the committee proposed creating 5,000 new fellowships each year. The fellowships would be provided to U.S. citizens pursuing an advanced degree in a STEM field and would allow recipients to study at an institution of higher education without their funding being influenced by current faculty research grants at that institution. The National Science Foundation (NSF) would administer the fellowships with support from other federal agencies in selecting the specific areas of need on which the fellowships would focus.

To grow the number of STEM bachelor degrees attained, the report suggested providing 25,000 new scholarships annually to be distributed to each state based upon its population and awarded to students based on a competitive exam. Scholarships would be awarded only to U.S. citizens who were studying STEM fields at an institution of higher education located within the United States.

In response to the suggestions set forth in *Rising Above the Gathering Storm* (2006)*,* the 109th Congress passed three pieces of legislation that were signed into law and contained STEM education policy. The National Aeronautics and Space Administration Authorization Act (P.L. 109-155) directed the development, expansion, and evaluation of educational outreach in science and space for K-12 schools. The National Defense Act of 2006 (P.L. 109-163) permanently created the Science, Mathematics, and Research Transformation program that had been piloted by the Defense Act of 2005 and was meant to address issues related to potential shortfalls of scientists and engineers in the national security workforce. The Deficit Reduction Act of 2005 created programs to supplement Pell Grants for students studying STEM fields. It also established the Academic Competitiveness Council to identify and evaluate all federal STEM programs.

2.1.2 The America Competes Act

The following year, President George W. Bush incorporated a number of the recommendations from *Rising above the Gathering Storm* (2006) in his State of the Union Address. During the 110th Congressional session that followed this address, the America COMPETES Authorization Act was passed and signed into law. This legislation contained a strong focus on STEM, specifically in K-12 education, research, and business incubation ("America COMPETES Act," 2007). However, the America COMPETES act was not a spending bill; rather, it was a bill that described policies Congress would like government agencies to follow. It also specified programs to achieve the goals of the legislation and endorsed a desired spending level to reach these goals. However, the America COMPETES act left the job of providing funding to the appropriations committee (Mervis, 2007).

The programs established under the America COMPETES Act were to be housed in the Department of Education, the National Science Foundation, and the Department of

Energy. Title VI of the Act authorized new grant programs in the Department of Education. Three programs to improve teaching in K-12 schools were authorized:

1. A Bachelor's Degree program to encourage current STEM majors to also obtain a teacher's certification.
2. A Master's degree program to improve the skills of current teachers.
3. A program to get 70,000 teachers certified to teach Advanced Placement and International Baccalaureate courses.

Additionally, Title VI established programs to help improve achievement in elementary mathematics, provide additional instruction in high need schools, and improve states' alignment with high school graduation requirements.

Title VII of the America COMPETES Act called for doubling expenditures on STEM-related education programs at the National Science Foundation over the next seven years. The new programs created at the National Science Foundation were to award grants to improve secondary school laboratories and to develop science master's degree programs at institutions of higher education. The rest of Title VII called for increased funding to currently existing programs such as Noyce Scholars, Math Science Partnership grants, and the STEM Talent Expansion Program. The Noyce Scholars program provides funding to institutions of higher education to support undergraduate scholarships, stipends, and programs to support STEM majors in becoming K-12 teachers (National Science Foundation, 2012b). Math Science Partnership (MSP) grants are awarded by the NSF and The U.S. Department of Education. The NSF MSP awards are through competitive grants for the improvement of STEM education (National Science Foundation, 2012a). The U.S. Department of Education MSP grants are made to states and then allocated by the states for STEM education activities (U.S. Department of Education, 2012). The STEM Talent Expansion Program is a competitively funded grant from the National Science Foundation to institutions of higher education to increase the number of Bachelors of Science degrees awarded in STEM fields (National Science Foundation, 2012c).

Title V of the act focused on creating new programs at the Department of Energy. These programs were focused on attracting students in middle and high school into the STEM pipeline. Pilot programs were enacted to expand STEM schools and provide experiential internships for students, especially those of low socio-economic status, at national laboratories. Centers were also established in every national laboratory region to develop and share STEM education best practices. Summer internship programs for teachers to improve STEM content knowledge were created, and programs were to be developed to expand the talent pool of students already in STEM fields in higher education.

2.1.3 Prepare and Inspire

In September 2010, five years after *Rising Above the Gathering Storm* and three years after America COMPETES, the President's Council of Advisors on Science and Technology issued *Prepare and Inspire: K-12 Education in Science, Technology, Engineering, and Math (STEM) for America's Future* (President's Council of Advisors on Science and Technology, 2010). This report expressed continued concern that based upon international comparison tests, K-12 students in the United States were lagging behind the students of other nations in STEM education. Recent evidence suggested that many of the most proficient STEM students were moving towards non-STEM fields. Committee members made seven recommendations that would address the underlying issues related to the declining U.S. STEM education prowess and encourage more high achieving students to move towards STEM fields.

1. The President should support the current state-led movement for shared standards in science and mathematics by providing financial and technical support to ensure high quality teacher professional development and assessments that are rigorous and aligned to the common standards.
2. Over the next decade, the federal government should help to ensure the recruitment, preparation, and induction support of over 100,000 new STEM middle and high school teachers who have degrees in STEM majors as well as strong content-specific pedagogical knowledge by providing support for programs designed to develop such teachers.
3. The federal government should support the creation of a national STEM Master Teacher Corps designed to recognize, reward, and engage the top five-percent of STEM teachers through significant salary and classroom fund supplements.
4. The federal government should create an advanced research projects agency for education with a mission-driven culture that draws on the strengths of both the U.S. Department of Education and the National Science Foundation. It should help to propel and support innovative technologies and platforms for teaching, learning, and assessment as well as effective integrated whole-course materials for STEM education.
5. A coordinated initiative to develop a wide range of high-quality STEM-based after-school and extended day activities should be developed that span efforts of

science mission agencies and after-school programs supported through U.S. Department of Education funding.

6. Over the next decade 1,000 new STEM-focused schools (200 high schools and 800 elementary/middle schools) should be created to serve all communities including many in minority and high-poverty areas.
7. New mechanisms should be created by the federal government that have substantially increased abilities to provide leadership within the National Science Foundation and the U.S. Department of Education by establishing a partnership between the two agencies. The committee proposed that a standing Committee on STEM education, housed within the National Science and Technology Council, should be developed that will create a federal STEM education strategy.

2.2 Outcomes

However, even with the awareness raised by these reports and the funding tied to the passing of new legislation, concern still continued about the quality and size of the next generation of STEM workers. As a whole, student growth in STEM areas was not what many had hoped**.** On April 29, 2008 approximately 500 representatives from government, business, and academia met in Washington, D.C to review the progress made in achieving the goals laid out in *Rising Above the Gathering Storm*. Overall, they found that many states had acted on the recommendations in *Rising Above the Gathering Storm.* However, they still believed that based upon international assessments American students were performing worse in all levels of education than many of their international partners. Moreover, this performance declined further as students progressed further through school (Arrison, 2008). Norman Augustine, chair of the 2005 committee, reported that many significant events had taken place since the release of the report but most of these positive events had taken place in other countries. Student progress on both national and international tests provided examples of both positive and negative results for U.S. students. Early student STEM success can be a predictor of later pursuit of a STEM career (Zeldin, Britner, & Pajares, 2008).

2.2.1 National Testing Outcomes

The National Assessment for Educational Progress is the largest nationally representative assessment of what American students know and how they can perform in various subject areas such as mathematics, reading, and science. NAEP provides results on subject-matter achievement and instructional experiences for populations of students and groups within those populations (National Center for Education Statistics, 2010a). On April 28, 2009 NAEP released the *National Assessment of Educational Progress (NAEP) long-term trend assessments in reading and mathematics.* The data show that, since 1973, the overall mathematics scores for 9 and 13-year-olds have increased but 17-year olds had no significant change. This is despite the fact that in the most recent NAEP data, the percentage of 17-year-olds who reported that their highest level of mathematics was algebra II (52%) or calculus/pre-calculus (19%) was higher than students reported in 1978 (37% and 6% respectively) (Rampey et al., 2009). The results from the 2012 NAEP showed the same gradual growth for 9 and 13 year olds, while the 17 year olds remain statistically unchanged (National Center for Education Statistics, 2013).

2.2.2 International Testing Outcomes

The Trends in International Mathematics and Science Study provides data on the mathematics and science achievement of U.S. 4^{th}- and 8^{th}-grade students compared to students in other countries. Data for TIMSS were collected in 1995, 1999, 2003, 2007, and 2011 (National Center for Education Statistics, 2010b, 2012). There was no detectable change in science achievement for U.S. students in fourth-grade between 1995, 2007, and 2011. For eighth grade science scores, there was significant change (513 to 525) from 1995 to 2007 but not from 2007 to 2011.

In mathematics, both fourth- and eighth-grade U.S. student scores improved in mathematics from 1995 to 2007. Fourth-grade scores also increased from 2007 to 2011, but not for eighth grade. However, there was no measureable change in the percentage of students performing at or above the international benchmark in either grade level. As a whole, the U.S. students have not performed well compared to international students as measured by TIMMS.

2.2.3 State Testing Outcomes

In Indiana over 400,000 people are employed in the life and health sciences industry, and strong preparation in K-12 science is needed to maintain and advance this STEM workforce. In 2013-2014, Indiana's K-12 public school enrollment was approximately 1,047,400 with a racial and ethnic diversity profile of 0.3% American Indian/Alaskan Native, 12.3% Black, 1.9% Asian or Pacific Islander, 10.1% Hispanic, 70.9% White, and 4.5% Multiracial. Forty-nine percent of Indiana public school students qualified for free or reduced lunch.

Starting in 2009, Indiana students were tested in science and mathematics during the spring at the 4th and 6th grade levels. Figure 2.1 shows the passing rates of Indiana students on the Indiana Statewide Testing for Educational Progress Plus (ISTEP+) science test (Indiana Department of Education, 2013).

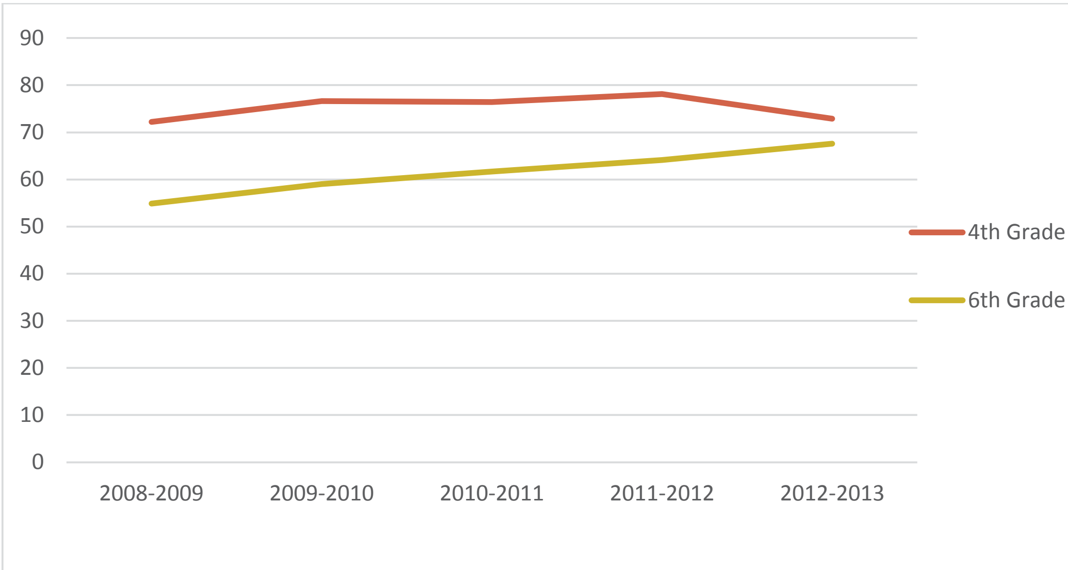

Figure 2.1 Percent of Students Passing ISTEP+ Science

In Indiana the trends in mathematics are similar to those on the state science test. Students take the ISTEP+ in mathematics starting in third grade and take it every year through eighth grade. Following student cohorts from grade level to grade level, passing rates increased from third grade to sixth grade but declined in the following grades. Figure 2.2 provides the passing rates of students by grade level each year.

Performance of Indiana students on the National Assessment of Educational Progress is consistent with the ISTEP+ results. On the 2009 NAEP, Indiana scored slightly above the national average in science in fourth grade with a scaled score of 153 compared to the national mean of 149. Indiana eighth grade students had a 2009 NAEP scale score of 152 compared to a national mean of 149 and a 2011 NAEP scale score of 153 compared to a national average of 151. However, the number of students passing at a basic proficiency level declined from the 4th grade (78%) to the 8th grade (67%) (National Center for Education Statistics, 2010a, 2013). These data show that while Indiana performs slightly above the national average, it still doesn't rank highly when compared to international competitors. This is an important statistic for a state with growing life science and STEM related industry.

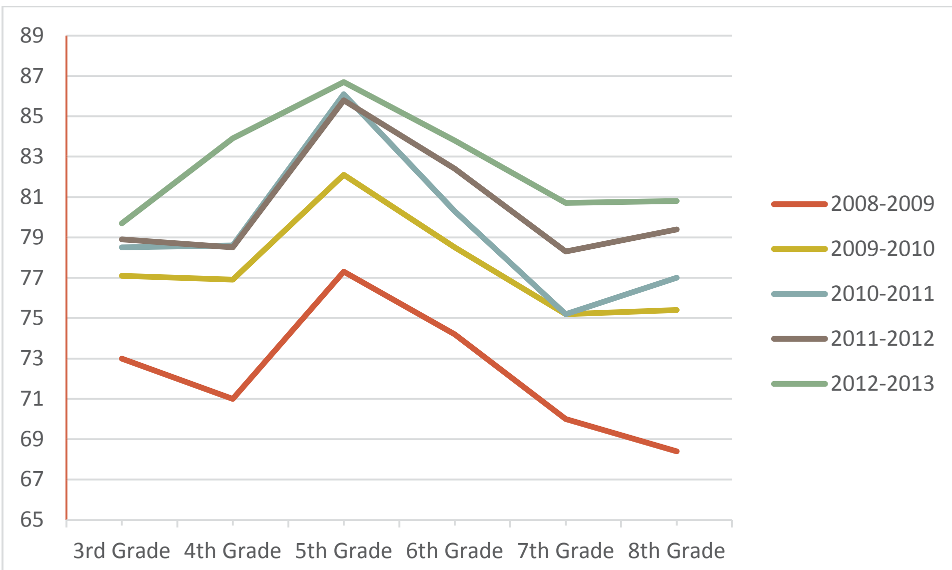

Figure 2.2 Percent Students Passing ISTEP+ Mathematics

Most states point to The No Child Left Behind Act (NCLB) of 2001 (PL 107-110) as the initiator of state-wide and national accountability testing. NCLB produced far-reaching effects on education across the United States. The law mandated: 1) state accountability systems; 2) required state testing programs that are standards-based; 3) required tests be given in grades three through eight annually in mathematics and English/language arts; and 4) required schools that do not meet adequate progress in consecutive years must allow students to attend a better school of their choosing (Sergiovanni, Kelleher, McCarthy, & Wirt, 2004). However, ten years after No Child Left Behind was signed into law, waivers were granted to ten states allowing them to opt out of its requirements, specifically the requirement that all students pass the state exams by 2014 (Feller & Helfing, 2012).

2.3 Standards, Programs, and Curriculum

2.3.1 National Standards

The national reform effort for STEM education also included a call for the development of measureable standards to help determine what students in the United States needed to learn in order to be competitive in a global market place and to provide an opportunity to focus teacher preparation and professional development. Several national organizations developed standards for their STEM subject area. The National Council of Teachers of Mathematics (1989), the American Association for the Advancement of Science (1989), the National Research Council (1996), and the International Technology Education Association (2000) developed standards for K-12 mathematics, science, and technology respectively. These standards specifically recognized the need for improved learning in their content area as well as the need for the integration of STEM subjects to enhance student learning.

More recently, the federal government supported the development of the Common Core standards in mathematics and language arts, as well as the Next

Generation Science Standards. Unlike the previous standards, states are required to adopt the common core standards for mathematics and English language arts, or college and career ready standards, if they want to be eligible to receive certain federal funds. Forty-five out of the fifty states have adopted the common core standards for mathematics. The concept behind the common core standards is to

> "… provide a consistent, clear understanding of what students are expected to learn, so teachers and parents know what they need to do to help them. The standards are designed to be robust and relevant to the real world, reflecting the knowledge and skills that our young people need for success in college and careers. With American students fully prepared for the future, our communities will be best positioned to compete successfully in the global economy."(Common Core State Standards Initiative, 2011)

Common core standards not only provide the content knowledge that students are expected to learn, but they also establish the processes and skills that students are expected to learn and be able to use within the context of the given subject area (Common Core State Standards Initiative, 2011).

2.3.2 Curriculum

In 1993 the National Science and Technology Council was established as a cabinet-level council that serves as the principal means within the Executive Branch of the United States government to coordinate science and technology policy across the federal government. A part of this council, The Committee on STEM Education, coordinates federal programs and activities in support of STEM education per the requirements of the America COMPETES Reauthorization Act of 2010. The three primary functions of this committee are to:

1. Review federal STEM education activities and programs and their assessments.
2. Coordinate STEM education activities and programs in the federal government with the Office of Management and Budget.
3. Develop and implement a five-year STEM education strategic plan.

As part of its charge, the Committee on STEM Education produced its inaugural annual report on the inventory of federal investments in STEM education for fiscal year 2010. The goals of the inventory were to:

1. Characterize federal STEM education programs.
2. Identify potential synergies within and across agencies.
3. Identify duplication, overlap, and program fragmentation.
4. Support the development of the five-year strategic STEM education plan.
5. Share effective STEM education program strategies and evaluation techniques within agencies.
6. Increase awareness of the current STEM education programs.

Information was gathered from various federal agencies through an online survey with confirmation of funding levels requested after submission by the agencies (Committee on STEM Education, 2011).

This inventory also showed that in fiscal year 2010 the federal government provided $3.53 billion dollars in funding for 421 different STEM education investments. The inventory focused only on 252 of these investments, totaling $3.44 billion. The remaining funds were either from earmarks, from the American Recovery and

Reinvestment Act, or less than $300,000 and did not meet the agreed upon criteria for the report. Of these funds, $312 million had a primary focus on investing in improving the performance of pre- and in-service teachers, while $1.086 billion went towards targeting underrepresented groups (Committee on STEM Education, 2011).

The Academic Competitiveness Council (2007) identified the existence of over 100 government-funded STEM programs designed for various grade levels or grade bands from kindergarten to post-graduate education. These programs include things such as outreach, weekend, after school and summer programs, and classroom curriculum. For fiscal year 2006, estimates indicate that the total government expenditures on these STEM programs through the NSF, Department of Health and Human Services, and Department of Education exceeded $3 billion.

Most of the new curricula developed were done in alignment with the national standards of the time for at least the primary content area being emphasized within the curricula. Government funding for curriculum development has historically increased following a call to action for improving K-12 education. For example, following the launch of Sputnik, NSF was directed to fund programs to improve mathematics and science education. NSF funded the development of the inquiry-based Physical Science Study Committee high school physics curriculum. A few years later, these same developers realized that inquiry-based science was needed at the elementary level as well. This led to the development of the Elementary Science Study, and, shortly after, the Science Curriculum Improvement Study and Science – A Process Approach (Pine & Aschbacher, 2006). These curricula focused on science but also incorporated mathematics. Over time, interest in these programs waned and they ceased to have wide utilization.

In the wake of the publication of *A Nation at Risk: The Imperative for Education Reform (1983)*, and with more calls for improving STEM education, specifically science and mathematics, NSF was again pushed to increase funding to improve materials and teacher preparation in mathematics and science. NSF responded by funding the development of, and research upon, several new inquiry-based science education curricula. Three of these programs, Insights, Full Option Science System, and Science and Technology for Children went through their initial development around 1990 and incorporated mathematics and technology in the curriculum (Pine & Aschbacher, 2006). All three of these programs utilized the national science standards and research on how students learn science in their development and have data showing that students learn more with these programs when compared to a control group using traditional text based science (Carolina Biological Supply Company, 2010; The Lawrence Hall of Science, 2011).

Concurrent with the funding of these science programs, NSF also funded the development of mathematics curricula. Many of these mathematics programs focused on helping students build conceptual understanding of mathematics and problem solving skills (Senk & Thompson, 2003). These NSF-funded mathematics programs incorporated STEM education learning traits such as real world applications, problem-solving, and group work, but not all of them made interconnections to other STEM disciplines. Programs such as AIM Higher! make connections to the other STEM fields, primarily engineering and technology, through the utilization and presentation of real world problems. AIM Higher! is framed around the National Council of Teachers of Mathematics national standards for mathematics. (Sutton & Krueger, 2002).

Over twenty different programs have been developed to teach students STEM skills through engineering education (Committee on K-12 Engineering Education, 2009). In Engineering Education, some of the most widely used programs in K-12 schools are Engineering is Elementary, Project Lead the Way, Engineering byDesign, and Design Quest.

2.4 Project Lead the Way

At the forefront of these engineering focused curricula, as represented by its depiction in *Rising Above the Gathering Storm,* is Project Lead the Way. PLTW is a not-for-profit company that has developed engineering and biomedical sciences curriculum. The PLTW Pathway to Engineering curriculum is designed as a four-year high school sequence of courses that includes both foundation courses and elective courses. Foundation courses are Introduction to Engineering, Principles of Engineering, and Digital Electronics (Phelps, Johnson, & Alder, 2006). Many universities across the country provide college credit for students who have completed PLTW courses and attend their institution (PLTW, 2010 website).

2.4.1 PLTW Evaluation Studies

Early research on PLTW showed some positive results in student performance. Bottoms and Anthony (2005) compared the achievement of students (N=274) who had taken at least two PLTW courses and comparable students who attended career and technical education but were not enrolled in PLTW. The purpose of their research was to determine if:

1. PLTW students in the High Schools that Work (HSTW) network achieve higher scores on HSTW Assessment for reading, mathematics and science tests than other similar students in career/technical fields and with all career/technical students.
2. PLTW students are more likely to complete the HSTW-recommended curriculum than other career/technical students.
3. PLTW students who take at least four years of college-preparatory mathematics and three years of science perform better than PLTW students who do not.
4. PLTW students have richer learning experiences than other students in their career/technical courses.
5. PLTW students experience more challenging and engaged educational experiences than other career/technical students.
6. PLTW students are more likely to see their high school education as more important than other career/technical students.
7. PLTW students are more likely to plan to pursue post-secondary education than other career/technical students.

All 274 students attended a school involved in the HSTW program. The HSTW program is being implemented in thirteen states and focuses on ten key practices for vocational/career and technical education high schools. These practices are based on the belief that students can master complex academics and technical concepts if the school environment encourages the students to make the effort to succeed (Southern Regional

Education Board, 2011). Data were collected using the 2004 HSTW assessment and student surveys. To have a comparison group, a sample was drawn from the general HSTW population. However, because the PLTW students had significantly different demographics than the general HSTW population, a random sample of career/technical students was also selected that had similar demographics to the PLTW sample. T-tests were performed for the statistical analyses.

To analyze research question 1, Bottoms and Anthony used data from the summative year-end HSTW assessment. When compared to their matched counterparts (N=274), PLTW students scored higher in mathematics ($p<.05$) and, when compared to the random sample (N=274) of all Career/Technical students, the PLTW students scored higher in both reading and mathematics ($p<.001$) as well as science ($p<.05$). It is important to note that the PLTW students in this study were more likely to have taken higher-level mathematics and science courses than their counterparts (Bottoms & Anthony, 2005).

For question 2, the recommended curriculum from HSTW is a sequence of academic courses students are encouraged to complete over their high school career. These sequences were grouped into three parts, English, mathematics, and science and then compared the completion of each part by percentage of students. A greater percentage of PLTW students (43%) completed all three parts compared to the matched career/technical students (35%), and all students (24%) as well as two parts (29%, 23%, and 25% respectively). Also, PLTW students who completed four years of mathematics and/or three years of science (question 3) performed at a much higher proficiency level on the HSTW Assessment than the PLTW students who did not (Table 2.1).

Table 2.1 *PLTW Students Scoring at Each HSTW Assessment Proficiency level*

	Below Basic	Basic	Proficient/Advanced
Completed 4 years of CP Math	17%	37%	46%
Did not complete 4 years Math	38%	55%	8%
Completed 3 years of CP Science	16%	31%	52%
Did not complete 3 years of CP Science	31%	41%	28%

Research question 4 was measured through multiple learning activities. These activities included completing challenging assignments at least monthly; using mathematics to complete challenging problems at least monthly; in career/technical courses, the students sometimes or often studied subjects related to their science classes; and they completed integrated projects that were for both a career/technical class and an academic class at least monthly. A higher percentage of PLTW students (64%) self-reported performing these activities than their matched career/technical students (54%) and the matched group from all career/technical students (52%).

Research question 5 was measured by examining indicators for literacy across the curriculum, numeracy across the curriculum, and engaging science curriculum and instruction. Literacy was measured through student opportunities to analyze, synthesize, and organize their thoughts through writing and presentations and the embedding of reading and writing strategies in all courses. Numeracy was measured through the number of years of mathematics taken, solving real world problems, working in collaborative teams, using technology to advance mathematics, and using mathematics to complete assignments in other classes. Engaging science was measured through the amount of times students designed and conducted projects, worked in teams on challenging problems, and studied science using authentic, real-world problems.

For literacy across the curriculum, researchers found that PLTW students experience slightly more emphasis on literacy across the curriculum (26%) than their matched counterparts in career/technical education (25%) and the greater HSTW population (22%). For numeracy, the difference was slightly greater at 47%, 38%, and 36% respectively and for science 29%, 29%, and 20%. Overall, no significant differences were identified in experiencing challenging and engaging instruction.

For research question 6, researchers found that PLTW students (41%) were less likely to see their high school education as being important when compared to the matched career/technical set (45%) but more than the matched set of all students (38%). Research question 7 may provide information as to why fewer PLTW students felt their high school education was important for their future. For research question 7, researchers found 70% percent of PLTW students planned to attend a four-year institution compared to 64% for the matched career/technical students and 45% for all career/technical students. This suggests that the PLTW students saw their future college education as having a greater impact on their life, since more planned to attend, than the other two groups.

Researchers in Iowa followed PLTW students from 8th grade through college with the goals:

1. Determine demographic characteristics.
2. Determine if PLTW students are more likely to take higher-level mathematics courses.

3. Determine if PLTW students experience greater cognitive improvement than non-PLTW students.

Students enrolled in PLTW were compared to a control group of students not enrolled in PLTW but attending a school that offered PLTW. Four cohorts were identified and labeled based upon the year of their high school graduation. These cohorts are the class of 2008 (N=352), 2009 (N=425), 2010 (N=420), and 2011 (N=542). The sample size of the control groups were kept the same as the PLTW cohorts. For student demographic information, when compared to the control group, PLTW students in this study were:

1. Less likely to be eligible for free and reduced lunch.
2. Less likely to be female.
3. More likely to have been enrolled in a gifted and talented program.
4. More likely to jointly enroll in community college and high school at the same time.
5. More likely to be white.

When comparing mathematics and science course levels taken, PLTW students were more likely to take higher-level courses. However, because courses were totaled for all available years and for all cohorts and because some cohorts had not finished high school, the data were weighted heavily towards the early cohorts and may not accurately reflect current trends.

To explore cognitive improvement, the Iowa Test of Basic Skills was used to collect 8th grade performance data (baseline data) and the Iowa Test of Education Development was used for 11th grade data. Preliminary results suggest that PLTW students performed better than the control group in math and science at both the 8th and

11th grade. On the preliminary 8th grade test, 80% of the future PLTW students scored above the 80th percentile in mathematics compared to 28% of the nonparticipants. In science, 55% of the PLTW students scored above the 80th percentile compared to 28% of the control group. On the 11th grade test 64% of the PLTW students scored above the 80th percentile in mathematics compared to 34% of the control group. In science, 61% of the PLTW students scored above the 80th percentile compared to 36% of the control group (Schenk et al., 2009).

Tran and Nathan (2010) performed a similar study in Wisconsin using 8th grade and 10th grade state standardized tests. A multilevel statistical modeling study with PLTW students (N=140) nested within teachers was conducted. The researchers utilized the enriched integration hypothesis, which implies that if science and math topics are effectively integrated into other areas, this increased learning time will increase student performance. Tran and Nathan hypothesized that students in PLTW courses, where math and science are integrated, should have increased gains and achievement on standardized tests when compared to a non-PLTW control group.

Data analysis used a two-level model. At level one, student demographics and prior achievement on standardized test scores in eighth grade were used to predict students' achievement in tenth grade mathematics and science. At level two, teacher experience was used as a predictor for student achievement. The relationship between student enrollment in PLTW foundation courses and student achievement was estimated controlling for student and teacher characteristics as given in level one and two. The samples were taken from a Midwestern city with a population over 500,000, using five high schools to draw the PLTW sample and the control group. All students in the sample had data from the states' standardized tests for mathematics and science in both eighth and tenth grade. For hypothesis one, it was found that PLTW students showed gains in both math and science achievement between the 8^{th} and 10^{th} grade; however, their gains were 10.76 points less in mathematics (p=.05) than a control group of identical size that was handpicked by the researchers from a best comparison group from same or similar schools. In science, the PLTW students' improvement was not statistically different compared to the improvement of the control group.

In another PLTW study in Wisconsin, a group of researchers conducted a researcher-led focus group during the 2006 spring semester. They utilized an unspecified sized sample of PLTW students and educators from four high schools and two middle schools that were in their first two years of implementing PLTW. Also, from these four high schools, 100 PLTW and 50 non-PLTW students were surveyed using the High School Survey of Student Engagement. This survey is given annually to high schools to assess the extent that their students were engaged in educational practices associated with high levels of learning and development (Center for Evaluation & Education Policy, 2010).

These two activities were performed to design and field-test assessment tools and processes for improving technology and pre-engineering instructional practices as well as to compile early evidence on the implementation of PLTW. The research questions for this study were:

1. Is there a difference in how these groups rate their feelings about the high school they attend?
2. Do PLTW students spend more time engaged in various learning activities?

3. Do PLTW students feel their school encourages them to engage in more active learning and futuristic thinking than other students?
4. Is there a difference in how PLTW and non-PLTW students see their recent experiences as contributing to their personal growth?

When compared to the non-PLTW students from their school, a greater percentage of PLTW students felt they had opportunities to be creative in class, were engaged in school, and that school made them feel confident in who they are (9-13% higher, percentages varied by the high school). The PLTW students were also more likely to say they were engaged in a variety of learning experiences (8-18%), and engaged in active learning and futuristic thinking (10-20%) (Center on Education and Work, 2007).

Van Overschelde (2013) provided a more extensive evaluation of PLTW using data from Texas. The data included approximately 7,000 PLTW students (4,100 in grade 12 during 2010-11 school year and 2,900 who graduated in 2009-10 school year) and a matched set of students selected through propensity score matching. Van Overschelde focused on four research questions:

1. How has enrollment in PLTW courses changed over the previous five years?
2. Does participating in PLTW increase performance on state mathematic and English language art assessments compared to matched non-PLTW students?
3. Does participating in PLTW increase college-going rates compare to matched non-PLTW students?
4. For students who go straight to the workforce, do PLTW students earn more money than the matched non-PLTW students?

To answer research question 1, course completion data was analyzed for five years. During these five years, PLTW enrollment in Texas increased from 4,498 students (2006-07) to 23,184 (2010-11). The researcher also found that enrollment of female (approximately 900 to 5300 or 586% increase), Hispanic (approximately 1450 to 7300 or 507% increase), and economically disadvantaged (approximately 1500 to 9650 or 650% increase) students had a larger increase compared to the increase of males (approximately 3,600 to 13,752 or 385% increase).

The researcher answered research question 2 through three different analysis of variances (ANOVA). The dependent variables were met standard, met college-ready standard, and scale score. For the 2010-11 senior class a higher percentage of PLTW students met the minimum state standard for mathematics $F(1,8187)=4.89$, $p<.027$). For those who the met mathematics college-ready standard, PLTW students had a higher percentage of students meeting this standard than the control group $F(1,8187)=8.58$, $p=.003$. For mathematics scaled score PLTW students had a higher mean scaled score $F(1,8187)$, $p<.0011$. For English language arts there was no statistically significant difference for any of the three measures.

For the 2009-10 graduate cohort, the findings were very similar to the 2010-11 senior cohort. A higher percentage of PLTW students met the minimum state standard for mathematics $F(1,5739)=7.15$, $p<.008$). For those who met mathematics college-ready standard, PLTW students had a higher percentage of students meeting this standard than the control group $F(1,5739)=9.09$, $p=.003$. For mathematics scaled score PLTW students had a higher mean scaled score $F(1,5739)=14.91$, $p<.0011$. For English language arts there was no statistically significant difference except the PLTW cohort had a higher percentage of students who met the basic standard $F(1,5709)=5.11$, $p=.024$.

For research question 3, the researcher found that a statistically significant increase in the percentage of PLTW students enrolling in Texas institutes of higher education than the matched cohort $F(1, 5739)=5.61$, $p=.018$. For the matched cohort, low-income students were less likely to enroll in higher education than their non-low-income peers. There was no difference for the PLTW cohort. To answer research question 4, the researcher computed median salary for the four quarters following high school graduation of students who were employed in Texas and did not enroll in post-secondary education. PLTW students had a median salary of $27,986 compared to their matched peers of $24,628.

Rethwisch, Starobin, Laanan, and Haynes (2013) studied persistence from high school to post-secondary education of PLTW students in Iowa using a matched control group created through propensity score matching. The research framework incorporated Pascarella's (1985) model for student learning and cognitive development. This model focuses on student background and precollege characteristics, structure, characteristics, and environment of the institution, interactions with socializing agents, and the quality of the students' effort. To account for these factors around institution, the models utilized included a second level for the district in which students attended. However, no additional factors were included on the district level and it was assigned only for random and not fixed effects.

The study found approximately 71% (38% to 2-year, 33% to 4-year) of PLTW students (N=885) continued directly into post-secondary education while only 52% (23%

to 2-year, 29% to 4-year) of the non-PLTW students (N=14,375) did the same. When the multi-level logit regression was run, being a PLTW student ($p<.001$, OR=1.59) was a predictor of transitioning directly to post-secondary education. An additional regression model was run to estimate the impact of PLTW when controlling for cumulative mathematics and science units. The researchers found that including additional mathematics and science coursework lessened that impact of PLTW on retention to higher education.

The findings from these PLTW studies are varied. Some studies have found that PLTW students have greater achievement than non-PLTW students in STEM subject areas during high school (Bottoms & Anthony, 2005; Schenk et al., 2009; Van Overschelde, 2013); while others did not find significant change in between student achievement based upon PLTW participation (Tran & Nathan, 2010). Findings also show that PLTW students felt like they had more opportunities and learning experiences in their classes when compared to their peers (Center on Education and Work, 2007) and were more likely to enroll in post-secondary education (Pascarella, 1985; Van Overschelde, 2013). None of these studies examined why schools adopted the PLTW curriculum and only two included potential institutional factors. Nathan and Tran (2010) included teacher level of experience within their models, which is related to teacher hiring and retention practices at their institution. Rethwisch, Starobin, Laanan, and Haynes (2013) included the district as a random effect second level variable, but did not include any other institutional factors at the school or district levels. The current research on PLTW has not investigated the impact of institutional factors on adoption and implementation outcomes. Understanding the many factors that may impact these variations in experiences and student performance is vital in introducing and maintaining successful STEM education reform. The National Science Resource Center proposed five areas that they found to be essential in creating and sustaining educational reform initiatives.

2.5 The National Science Resources Center's Five Areas for Reform

The National Science Resources Center (1997) proposed a model for creating systemic reform in science education that is valid in many if not all other areas of K-12 education. Their reform model focuses on five areas found to be necessary if systemic change is to happen in STEM education.

1. Curricular Materials – curricular materials are the books, materials, programs, etc. that schools select to teach in their classrooms. In the context of the United States, curricular materials can encompass district and school policies for instruction and include the adoption and implementation guidelines of the curriculum (Ferrini-Mundy & Floden, 2007). In Indiana these decisions are based upon local decisions and policies.
2. Professional Development - professional development should address new skills and knowledge that teachers need to teach in a hands-on, problem-solving, student-focused classroom. This means that teachers will need to develop new beliefs in how learning should look in their classroom and unlearn much of what they have been previously taught (Kimmel, Carpinelli, & Rockland, 2007; Loucks-Horsley, 1995). These approaches must not be a short-term process. Lasting changes in teachers' behavior do not come from short-term professional

development opportunities nor from isolated instructional behaviors (Rockland et al., 2010; Sorge & Russell, 2000).

In order to teach, student teachers need appropriate content knowledge of the subject they are teaching if they are to help students learn. It is important to understand the link between teacher knowledge and student learning (Loucks-Horsley, 1999). Teachers without appropriate professional development have impeded the successful implementation of superior science programs (Dana, Campbell, & Lunetta, 1997). Shulman (1986) introduced the idea of pedagogical content knowledge (PCK). He contends that content knowledge and pedagogy are not mutually exclusive domains.

PCK is not the same as content knowledge or general pedagogical knowledge, and involves knowledge of teaching strategies that incorporate appropriate conceptual representations, addresses learner difficulties and misconceptions, and fosters meaningful understanding. It also includes knowledge about students' pre-conceptions and misconceptions of the learning at hand and allows educators to better understand the cognitive demand of the tasks introduced to their students and when and how to make the problem or task easier or more difficult.

3. Materials Support – depending upon the curricular materials selected and the subject area, there may be a need to replenish, clean, or replace materials that are being used. Many of the previously mentioned NSF funded STEM programs from science, engineering, and technology require consistent replenishment or replacement of materials.

4. Administrative and Community Support - research on educational change has shown that teachers, principals, central office staff, and others, such as state departments of education, play important but different roles in school improvement (Crandall, 1983). Effective principals create a climate of high expectations and help their teachers, through in-service training, to use effective classroom strategies. These principals generate teacher commitment and energize them on teaching and school effectiveness (Manassee, 1983).
5. Assessment/Evaluation - Research has demonstrated the importance of providing students with consistent, specific feedback for achieving content standards. A comprehensive assessment system should contain multiple and varied data points, be clearly aligned with standards and learning goals, include formative and summative assessment, reveal strengths and gaps in students' understandings, contribute to student learning, and inform instructional decisions.

Given past and current levels of funding for the development of STEM curricula, teacher professional development, and overall support for STEM education, the lack of significant gains by U.S. students in comparison to other countries has contributed to the ongoing concern over what could be classified as a failure of the education and/or policy system. However, while it appears that these policies overall have not met intended goals, there are multiple examples of policies resulting in states and school districts implementing STEM Curricula and/or programs and showing significant improvement in student STEM performance. STEM related initiatives such as those in Delaware (Wood & Collette, 2004), Alabama (Ricks, 2008), Washington (Ferguson, 2009), and Philadelphia (Ruby, 2006) serve as moderate to large scale examples of how policies and programs can be successfully implemented and effectively increase student STEM learning.

2.6 Policy and Education Policy Research

Early policy researchers found that policy implementers did not always do as they were told. Instead the implementers at various levels responded in unpredictable and sometimes resistant ways. This resulted in program expectations not being met and wide variability in program outcomes depending upon the implementers (Pressman & Wildavsky, 1973). Researchers also found that policy outcomes are dependent upon how the individuals within the policy system interpret and enact the policy (Elmore, 1977; McLaughlin, 1987; Van Meter & Van Horn, 1975).

2.6.1 First Generation of Policy Implementation

Results of the initial work done in policy implementation, called the first generation of policy implementation, showed that governmentally sponsored programs did not meet their legislative objectives (Lester, Bowman, Goggin, & O'Toole Jr, 1987; Pressman & Wildavsky, 1973). Factors, such as organizational size, internal organizational interactions, dedication, capacity, and complexity shaped responses to policy (McLaughlin, 1987). Much of the first generation implementation research demonstrated that federal or state initiated programs in education were doomed to fail, due to local implementation resistance and conflict with other priorities on the local level (Derthick, 1976; Pressman & Wildavsky, 1973).

One early educational analysis was the Rand Change Agent Study (Berman & McLaughlin, 1974), a multi-year study of Title III of the 1965 Elementary and Secondary

Education Act (ESEA), the Right to Read Program, the 1968 Vocational Education Act, and Title VII of ESEA. The policies evaluated in the Rand Change Agent Study represented the first significant federal-level attempt to create change in local educational practices (McLaughlin, 1991). Rand Change Agent Study researchers found that, on the local level, school personnel rarely felt that policies or organizational boundaries greatly influenced their day-to-day work in their classroom. Instead, teachers believed that colleagues, non-formal agencies, and professional organizations falling outside the formal policy realm were the significant factors in their actions and practices throughout their careers.

Results from the first generation of education policy analyses identified three broad patterns of practice: keeping traditions, adapting context and expectations, and reinventing practice that would challenge institutional expectations, norms, and directions. It is an important point for policy and its implementation that each teacher responds differently to similar students and that district, school, and department contexts influenced these teachers in different ways (Berman & McLaughlin, 1974). These findings were supported by other early implementation research in education (Barro, 1978).

2.6.2 Second Generation of Policy Implementation

The second generation of policy analysts focused on the development of theories and frameworks (deLeon & deLeon, 2002; Lester et al., 1987; Sabatier, 1986) in order to identify factors that contribute to the attainment or non-attainment of the policy's goals and objectives (Lester et al., 1987). The second generation tried to explain variation in implementation of programs and units through specific variables and through the use of conceptual frameworks. Collectively, the work done in the second generation provided an overview of the complexity of policy-making and the factors that impede or support successful implementation but did not link with individual behavior (Sabatier & Mazmanian, 1980). Within the second generation there were three types of approaches to research: Top-down; bottom-up; and a blend of the two. The initial group of analysts in the second generation used the top down approach to policy analysis (deLeon & deLeon, 2002; Lester et al., 1987; Sabatier, 1986). A top down approach to policy analysis begins with a policy decision by governmental officials and then evaluates:

1. To what degree are the actions of the policy implementers and target audience consistent with the objective of the policy?
2. To what degree were the policy objectives achieved over time and how were the impacts consistent with the objectives?
3. What are the primary factors affecting the outputs and impacts of the policy including those relevant to the official policy and other politically significant ones?
4. How was the policy transformed over time because of experience (Lester et al., 1987; Sabatier, 1986)?

Van Meter and Van Horn (1975) proposed six primary variables that link policy to performance in the implementation of that policy:

1. Policy objectives and standards.
2. Resources of the policy.
3. Inter-organizational communication and policy enforcement.
4. Characteristics of the implementing agencies.
5. Current economic, social, and political conditions.

6. Disposition of the implementers (Van Meter & Van Horn, 1975, pp. 462-474).

Sabatier and Mazmanian (1980) suggested a model of six necessary variables for effective policy implementation:

1. Clear and consistent objectives.
2. Adequate causal theory.
3. Implementation structures to enhance compliance by implementers such as officials and target groups.
4. Committed and skillful implementing officials.
5. Support from interest groups and sovereigns.
6. Changes in economic conditions that do not substantially undermine the other variables (Sabatier, 1986).

The bottom up approach suggested that a more accurate understanding of implementation could be gained by analyzing policy from the viewpoint of the policy implementers and their target population (Matland, 1995). The bottom up approach was developed by researchers such as Elmore (1978), Hjern (Hjern, 1982; Hjern & Porter, 1981), and Lipsky (1971) and focused on identifying the network of actors involved in program delivery in one or more areas, then asked these individuals about their goals, activities, strategies, and contacts. Researchers then used this information to understand the network of local, regional, and national actors involved in the planning, financing, and implementation of the relevant government and non-governmental programs (Lester et al., 1987; Sabatier, 1986).

Sabatier (1986, 1991) proposed a synthesis of these two approaches that was primarily concerned with the construction of theories around the policy implementation process. His framework combines the unit of analysis prevalent in the bottom up approach, which Sabatier calls Constraints and Resources of Subsystem Actors, with the top down concern over which instruments and socioeconomic conditions help to constrain behavior, referred to as Events External to Subsystem and Policy Subsystem. The framework assumes that stable system parameters such as rules, the problem area, and resources impact external events such as socio-economic conditions, government, and other subsystems. These two parameters then affect the constraints and resources of actors within the subsystem. From there the constraints and resources directly impact the policy subsystem, which in turn impacts external events and the cycle continues. Sabatier's model is important because of his suggestion of taking a much more longitudinal approach, a minimum of ten years, thereby allowing implementers the time to adapt to and effectively implement policies. His model also represented an early effort to account for the circular effect in the implementation process, where each level has an impact on the other levels.

Elmore (1996) looked at the results of educational policy research on large-scale reform and found that the nearer an instructional-innovation gets to the core of what takes place between teachers and students in a classroom, the lower the likelihood it will be implemented and sustained on a large scale. In other words, if the reform greatly impacts how a teacher teaches or interacts with his or her students, the less likely it is to be successfully implemented on a large scale no matter the success it has seen on a smaller scale. This finding has a direct impact on the types of policies that need to be created and how they are implemented.

2.6.3 Education Policy Implementation Factors

As education implementation research progressed, researchers found that programs were being implemented in compliance with the given policy or mandate, yet they were falling short of the quality envisioned or impact desired (Elmore & McLaughlin, 1983). McLaughlin suggests that program quality and impact are best analyzed by focusing on the local, micro-level, as well as the connections between the various governing levels over implementation (McLaughlin, 1987, 1991). McLaughlin (2005) found that in education, most policy outcomes are due to local capacity and will. Local expertise, organizational routines, and available resources to support the implementation of a policy or program create differences in the ability of the organizations to plan, implement, and then sustain a new program or policy.

Twenty-first century school leaders have new responsibilities amid rapidly changing policy conditions and contexts for learning. These responsibilities include managing and monitoring curriculum development/selection, assessment, reporting, educational staff performance management, selection, and development; mission building and reform management; school accountability; and community relations and marketing (Ingvarson, Adnerson, Gronn, & Jackson, 2006). However, leaders in all sectors of society are often guided by the history of the organizations they lead. This is true in public education, where school leadership is frequently recruited from within the current ranks of practice (Elmore, 2000).

Research on the factors that impact student learning has been extensive. A meta-analysis done on a collection of studies by McREL (2003) found that student factors (home environment, learned intelligence/background knowledge, and motivation) accounted for approximately 80% of the variance in student achievement. Teacher-level factors (instructional strategies, classroom management, and classroom curriculum design) account for approximately 13% of student learning. School level factors (collegiality and professionalism, safe and orderly environment, a guaranteed and viable curriculum, challenging goals and effective feedback, and parent and community involvement) account for the final 7% (Marzano, 2003). In their research, Leithwood, Louis, Anderson, and Wahlstrom (2004) found that leadership accounted for 25% of total direct and indirect effects on student learning. Basic leadership practices for which they looked included setting directions, developing people, and redesigning the organization. Of these three, setting direction was found to have the greatest impact upon student learning.

It has been proposed that lasting change in a school can only come through transformational leadership and a fundamental change in the organization of educational leadership (American Educational Research Association, 1999). Others claim issues have arisen because of the decentralization and pluralistic nature of educational governance (Burch, 2007). Behavior in organizations is determined by the need and desire to comply with accepted beliefs, rules, and norms (Fitz & Halpin, 1994). Principals are a first order barrier to change. However, in the end, teachers are the final agent in implementing educational policy (McLaughlin, 1987). If teachers work in an environment where they have few opportunities or incentives to learn about revising their practices, they are less likely to enact reforms. Schools and their districts have great influence on providing teachers with these environments (Spillane & Thompson, 1997).

2.6.4 Policy Instruments

Policies like No Child Left Behind and Race to the Top can be grouped by the instruments that are used. These instruments can be grouped into four different categories: mandates, inducements, capacity-building, and system-changing strategies. Mandates are rules and regulations to directly impact the choices and actions of those being governed. Inducements include the exchange of money, status, and/or other benefits in return for selecting the choice(s) or action(s) specified by the policy. Capacity building, like inducements, uses money, status, and benefits for investing in human capital to make the individuals act in a certain way. Capacity building specifically focuses on investment in materials, intellectual, or human resources. System changing attempts to bring about the desired outcomes by redistributing power and authority among those involved (McDonnell & Elmore, 1987). However, as research on policy implementation and education policy implementation progressed, researchers found that many programs were successful and being implemented as desired by the policy. Yet there was still variation in how the same program was being implemented in different locations and in the outcomes being observed. This led many policy researchers to realize that policy implementation plays a significant role in the extent to which a policy is effective.

While much was learned through policy implementation research, many felt that not enough was learned. Ingram (1990) wrote that, despite the extensive literature published on policy implementation, it had only heightened the appreciation of the field but not reached clarity. deLeon (1999) made a similar observation when stating that the policy implementation literature since the 1970s had developed little operational theory of implementation and had reached its intellectual end. O'Toole (2000) suggested that other scholarly work in other policy fields had linkages to advancing the work being done in policy implementation and could serve as alternative approaches to policy implementation research. He recommended incorporating work from theories such as communication, regime, rational choice, and contingency to advance the field. Fredrickson (1999), when looking at the scholarly work in other areas of policy analysis, suggested that several of these areas had informed the field of public administration in general and helped revitalize that field and should be examined to support policy implementation analysis. Fredrickson's position is supported by Polski and Ostrom (1999), who asserted that any given policy situation overlaps with many other policy situations, such that the activities of one situation affect others. No single discipline addresses all the human issues associated with complex social situations.

2.7 Institutional Theory

Implementation research depends heavily on institutional scholarship. Policies and programs rely on institutional structure and institutional action throughout the process of policy development and implementation. In the past 25 years, researchers have strengthened links between institutional theory and analysis to research in education policy and practice. Institutional thinking assumes that large institutions, such as those in education, have practices that are often contested or challenged. These practices can take many different shapes and forms, which may make the practice more appealing to one group of actors than another (Meyer & Rowan, 2006). Much of this early work was done by sociologists looking at studies of broader organizational and social phenomena (Burch, 2007). However, institutional analysis has also been used by education scholars. Burch and Spillane (2005) used institutional analysis to analyze district leadership and middle level staff and their impact on instructional change. Ogwa (1992) used it to evaluate the impact of leadership in schools. Killeen and Sipple (2000) examined the impact of school consolidation on transportation policies. Coburn (2001) evaluated how teachers mediated reading instruction policy by studying the persistence of change in structures, norms, and patterns of relationships in the schools.

Institutional researchers examine the ways that norms and belief systems in the environment shape social structure, culture, and routines in organizations. Hjern and Porter (1981) describe institutional structures as being more self-selected than designed through authoritative directives and as being formed by the initiative of individual actors in relationship to a program. Institutional analysis can be described as the stakeholder analysis of government or non-government organizations that implement or support the action choices that underlie a policy reform. It is informed by three primary premises:

1. Government is not a solitary actor.
2. Different actors compete for power and resources.
3. Decisions made at a higher level are modified at the local level (World Bank, 2008).

Killeen and Sipple (2000) used institutional theory and analyses to highlight the rules, norms, and societal pressures and expectations to better understand school consolidation and transportation policy. Their analysis looked at legitimacy, the level of cultural support for an organization, and how the survival of an organization is tied to its ability to link its activities to the broader and more socially-determined forces in the environment. They found that districts often stress institutional conformance over gains in efficiency or achievement. This societal and cultural impact led, over time, to districts shifting their needs and focus resulting in community changes to conform to the new rules and norms.

Burch and Spillane (2005) looked at how schools implemented district policy across two domains. One domain examined the interface between administrators' views of subject matter and the practices they used in improving instruction in those content areas. The framework demonstrated ways in which norms of the subject matter impact policy-making and governance of the schools and those subject areas. The second domain focused on an institutional analysis of organizational practices in relationship to domain one and how organizational structures and practices act as carriers of broader social and cultural norms. They found that staffing at the school and district levels often reflected these social and cultural norms. This often meant that school and district leaders had stronger backgrounds in literacy first and mathematics second, while other subject areas were often not represented. This leadership background was reflected in how local policy makers created and implemented policy.

Coburn (2001) used institutional theory and analysis to evaluate the impact of the environment of the larger school/district institution upon the classroom. Specifically, the research looked at three teachers in two schools and their reading instruction and practices. Twenty-eight total interviews were conducted with the three teachers focused on developing histories of their classroom practices and the connections the institution had upon these practices. Coburn (2001) found that teachers responded to environmental pressures on their reading practices by drawing upon preexisting views and practices and utilizing their beliefs about the nature of reading instruction, how students learn, and current school rules-in-place to construct their reading practices.

Each of these institutional studies shows the influence institutional practices have upon how schools and districts go about the process of education. Institutional factors such as cultural norms, rules in place, and pressures to conform to certain practices within the school can significantly affect the outcomes of a policy or program within a school.

2.7.1 Institutional Analysis and Development Framework

Institutional analysis, through the work of Elinor Ostrom (2011; Ostrom et al., 1999) and their Institutional Analysis and Development framework, has greatly reshaped policy research. IAD was first developed in the 1960s by Elinor and Vincent Ostrom to help understand policy related to common-pool resources, such as natural resources like water management in community owned irrigation systems and human made resources like open source collaborations (Bushouse, 2011). The goal of the IAD framework was to help analysts comprehend complex social situations and divide them into manageable sets of activities. It was also designed to help identify and evaluate patterns of interactions that are associated with behavior in a certain arena and the associated outcomes (Polski & Ostrom, 1999).

Over time the IAD framework (see Figure 2.3) has been applied to additional areas of policy analysis. This was because IAD was designed to work with a wide array of theories such as game theory, rational choice theory, economic theory, social choice theory, transaction cost theory, common-pool theory, and covenantal theory. Theories enable the analyst to determine which elements of a framework are relevant to certain questions and to make general working assumptions about the strengths of each element.

Further, the development and use of models are important because models allow the analyst to make precise assumptions about a limited variable set and parameters. This allows precise predictions to be made about the results of combining these variables within a certain theory.

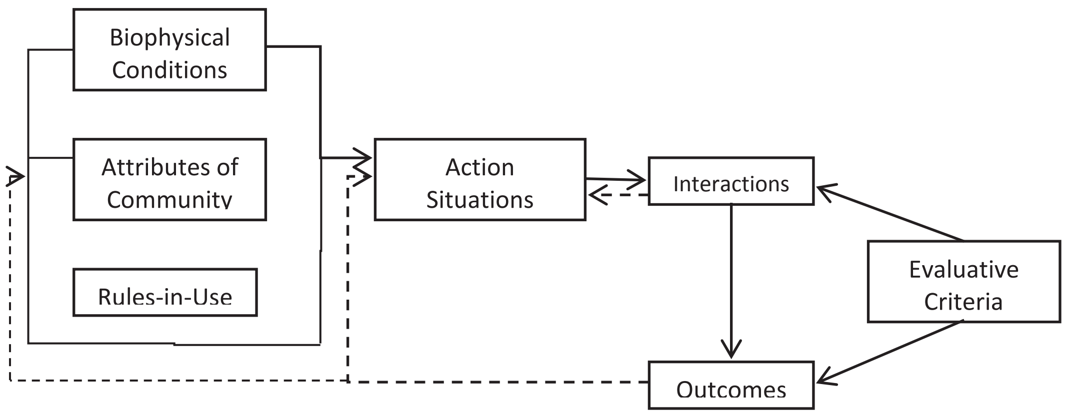

Figure 2.3 The Institutional Analysis and Development Framework

Source: Ostrom (2011)

IAD was developed as a general framework or multi-tiered conceptual map that allows for the integration of work from researchers involved in a wide range of disciplinary perspectives. IAD relates to how the rules of the game influence the given incentives presented to individuals and their subsequent behavior. The framework suggests three levels of decision-making: constitutional, collective choice, and operational. A nested structure of rules guides interactions and decisions made by actors at each level through constraints and incentives established at higher levels (Ostrom et al., 1999).

Action situation. A major component of IAD is the action situation. An action situation is an analytic concept that allows the isolation of the immediate structure affecting a process of interest to an analyst to explain regularities in human actions and results, and the potential to reform them. The structure of an action situation (Figure 2.4) includes:

1. The set of actors who can be a single person or a group functioning as a corporate actor.
2. The positions to be filled by participants.
3. The set of allowable actions and how they link to outcomes.
4. The possible outcomes related to an individual's actions.
5. The level of control each actor has over choice.
6. The costs and benefits, assigned to actions and outcomes that serve as incentives or deterrents.
7. The information available to the actors about the structure of the action situation (Ostrom, 2011).

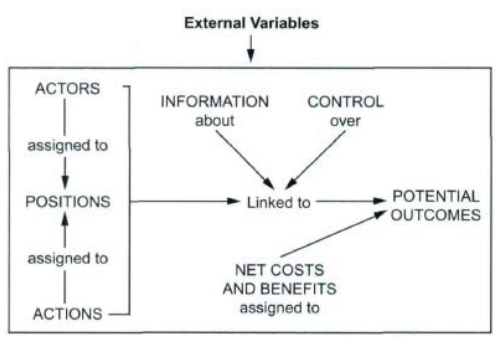

Figure 2.4 The Internal Structure of an Action Situation

Source: Ostrom (2011)

Underlying action situations are sets of rules that individuals use to order their relationships and community understanding. These rules are shared concepts and ideas of the individuals involved in that action situation that refer to enforced prescriptions about which actions are required, prohibited, or permitted. Rules have a lack of clarity, misunderstanding, and change. Seven types of rules affect the structure of an action situation:

1. Boundary rules that define a set of positions and how many individuals can hold each position.
2. Position rules that determine how individuals are chosen to hold positions and how they leave these positions.
3. Scope rules specify the outcomes that may be affected and the inducements for each outcome.
4. Authority rules assign the set of actions to a position.
5. Aggregation rules specify the decision functions used at a particular point to map actions into intermediate and final outcomes.
6. Information rules provide channels of communication between individuals in positions and specify the form in which these communications take place.
7. Payoff rules provide how benefits and costs are distributed between individuals in each position (Ostrom, 1986).

Researchers have employed the IAD framework in a number of areas, such as ecosystem management (Imperial, 1999), land development (Feder & Feeny, 1991), common-pool resources (Tang, 1991), higher education (Richardson, 2004), the management of fisheries (Sen & Nielsen, 1996), and the shared information and resources contained on the Internet (Hess & Ostrom, 2007). The IAD framework exhibits a history of great flexibility of use and has been used in many different areas of policy analysis. It also provides researchers the ability to delve deeply into actions and their outcomes in complicated situations such as the selection and implementation of educational programs in the K-12 settings.

2.8 Conclusion

Policy implementation research has gone through multiple generations since its early inception in the 1960s (Elmore, 1996; Sabatier, 1991). The findings, in relationship to education policy implementation, show that programs may be implemented in relationship to the policy but still may fall short of the desired impact (Elmore & McLaughlin, 1983).

Results from the implementation of education programs have varied depending upon the organization implementing the program (Berman & McLaughlin, 1974; Feller & Helfing, 2012; McLaughlin, 1987, 1991; National Center for Education Statistics, 2010a). The findings from studies on PLTW exhibit promise in showing enhanced student performance and interest in STEM education and STEM education careers (Bottoms & Anthony, 2005; Center for Evaluation & Education Policy, 2010; Center on Education and Work, 2007; Nathan et al., 2010; Schenk et al., 2009). Indiana has spent millions of dollars supporting PLTW implementation across the state through the Department of Workforce Development and the Department of Education.

Understanding the mitigating factors involved in the implementation of the Indiana Department of Workforce Development policy around PLTW funding should add new insight into the impacts of the attributes of the community and inform not only the implementation of PLTW but policy around other STEM programs. The Institutional Analysis and Development Framework provides an excellent opportunity to enhance understanding of these factors that impact the policy implementation on the local level in support of STEM education.

CHAPTER 3. PROCEDURES AND DATA COLLECTION

Creswell (2013) states that there are four basic philosophical assumptions that have implications in the practice of research. The ontological assumption poses that reality is multiple and seen through many views. Analyzing multiple realities through the use of a multilevel statistical model with the Institutional Analysis and Development (IAD) framework (Hess & Ostrom, 2007; McGinnis, 2011) is fitting. Within the IAD framework, attributes of the community have a direct and indirect effect on the outcomes of an action situation. Attributes of the community are all the relevant parts of the social and cultural context related to the location of the action situation. Outcomes, as related to the IAD framework, are influences by the action situation as well as exogenous factors such as attributes of community (McGinnis, 2011). This research focused on school and district level community attributes and their influences on outcomes related to the adoption and implementation of PLTW in Indiana schools.

3.1 Study Design

This investigation was a quantitative research study that used a multilevel model of nested data to examine the mitigating factors of the attributes of the community on student level outcomes (level 1 of the model). Attributes of the community are comprised of district/community level data (level 3 of the model) and school level factors (level 2 of the model). Data were analyzed through descriptive and inferential statistical analysis.

3.2 Study Participants

Each of the following groups of students were divided into STEM and non-STEM majors: PLTW students, non-PLTW students who attended a PLTW school, and students who did not attend a PLTW school (see Figure 3.1). Descriptive statistics were calculated to provide a broad picture of all groups and subgroups of students by examining their demographic characteristics (gender, race, socioeconomic status). Analysis of the multilevel model with nested data was done using Hierarchical Linear Modeling (HLM). The use of HLM software allows for the creation of linear models with explanatory variables that account for variation at each of the three levels of the analysis.

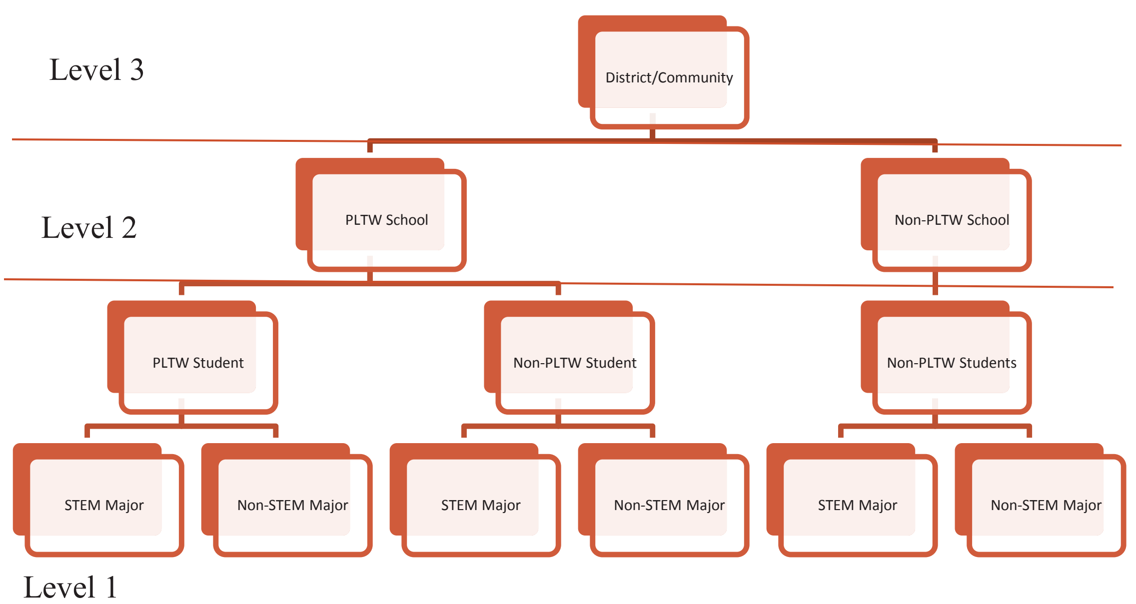

Figure 3.1 Group of Analysis

3.3 Hypotheses

1. Attending a school that offers PLTW will increase the likelihood of students majoring in a post-secondary STEM program. This odds ratio will be greater if they have taken PLTW courses.
2. The factors for college persistence will differ for students at PTLW schools, students at non-PLTW schools, and PLTW students.
3. The factors that are statistically significant for majoring in STEM will be different for PLTW schools and non-PLTW schools. They will also be different for PLTW students.
4. Attending a school that offers PLTW will increase the likelihood that a student will persist from his/her freshman to sophomore year of college.
5. District/community level factors focused on educational attainment and income/wealth will be statistically significant in impacting the likelihood PLTW students major in STEM. These factors will differ for non-PLTW students at PLTW schools and students at non-PLTW schools.
6. For PLTW students, the odds ratios for statistically significant district/community level factors will be greater than the odds ratio of school and student level variables for majoring in STEM. The odds ratio for these factors for PLTW students will be proportionally greater for PLTW students than non-PLTW students at PLTW schools and students at non-PLTW schools.
7. District/community level factors focused on educational attainment and income/wealth will be statistically significant in impacting PLTW students persisting from their freshman to sophomore year of college. The statistically

significant factors for PLTW students will be different from the statistically significant factors for non-PLTW students at PLTW schools or students at non-PLTW schools for persisting.

8. For PLTW students, the odds ratios for statistically significant district/community level factors will be greater than the odds ratio of school and student level variables for persisting from their freshman to sophomore year of college. The odds ratio for these factors will be proportionally greater for PLTW students than non-PLTW students at PLTW schools and students at non-PLTW schools.

3.4 Data Collection

To the outcomes associated with the hypotheses, data were collected and combined from multiple sources. A complete list of the data collected was provided in Figure 2, located in chapter 1. Level 1 data, student level data, were created by merging data provided by the Indiana Department of Education (IDOE), The Indiana Department of Workforce Development (DWD), and the National Clearinghouse (via the Indiana Commission for Higher Education (ICHE)). The IDOE provided de-identified student level demographic and academic data. DWD data, which contained PLTW course information, were converted by the IDOE to use the same student identifiers as the data provided by IDOE. The ICHE, through its partnership with IDOE and the National Clearing House, provided college level data on all students from the 2010 Indiana high school graduating classes using the same identifier as the IDOE. These data were then combined into a single data set based upon the student identifier.

Level 2 data, school level data, were gathered from data publicly available on the IDOE website as well as school level PLTW class implementation data from PLTW. Level 3 data, district/community level data, were collected from the National Center for Education Statistics' district level data. These data were created based upon the 2010 census information and organized by school district. Additional district level data were created by classifying each district as rural or non-rural. The rural/non-rural classification was based upon the designation given by the Universal Service Administration Company (USAC) - a not-for-profit - assigned by the Federal Communications Commission to oversee affordable telecommunication services and e-rate, which provides funding reimbursement grants to schools for telecommunications and Internet access (USAC, 2014).

3.5 Data Analysis and Interpretation

3.5.1 Statistical Approach

Descriptive statistics were used to describe the PLTW schools and non-PLTW schools, their communities, and the six groups of students. This descriptive analysis provides details of the general configurations of the communities, schools, and students. The data that were used to answer the research questions are contained at three levels (district/community, school, student), with each level of data nested within the level above it. To analyze these types of data a multi-level analysis using Hierarchical Linear Modeling was conducted. Multilevel nested data structures have been analyzed in many areas of research. A few examples include business research (Liao & Chuang, 2004; Peterson, Arregle, & Martin, 2012), medical research (Carey, 2000; Friedmann et al., 2013; Hruschka, Kohrt, & Worthman, 2005) and educational research (Dettmers, Trautwein, Ludtke, Kunter, & Baumert, 2010; Nagengast & Marsh, 2012).

Analysis of these multilevel data structures containing data that are nested within levels can create statistical problems with the heterogeneity of regression slopes, the estimation of standards errors, and issues with aggregation bias. Aggregation bias arises by making the assumption that what is true about the group is true about the individual and can occur when a variable takes on different meanings at different levels of the model. Estimation of standard errors issues can occur when student level data are treated as independent even though factors from the levels in which they are nested impact them. Similarly, issues with similar regression slopes within nested data can also occur because of the similarity of the nested situations. In other words, student achievement based on race or socioeconomic status may vary depending upon the school and district the student attends. (Lee, 2000; Woltman, Feldstain, MacKay, & Rocchi, 2012).

Many techniques and applications have been developed to combat these potential issues when working with nested data (King, Hernandez, & Lott, 2012; Steenbergen & Jones, 2002). This study avoided these nesting issues by utilizing Hierarchical Linear Modeling. HLM uses multi-level linear regression that allows for the analysis of effects from both within and between levels using a nested design and eliminates the aforementioned statistical difficulties. Figure 1.2 provides a diagram of the levels and variables that will be used within the models. Nesting of students within schools and schools within districts to measure the impact of different levels of factors is an appropriate use of HLM.

3.5.2 Procedure

When running an HLM analysis, the first step is to determine the proportion of the variance between groups that lies at level-2 and level-3 of the model. This is called the intraclass correlation (ICC). If the ICC is considered to be trivial, less than 10% at both levels, then multi-level analysis would not be appropriate for the research question(s) (King et al., 2012; Lee, 2000) as these upper levels would account for little or none of the variation in outcomes. However, previous analyses on a subsection of these data have shown that school level data are significant in relationship to PLTW student level outcomes (Pike & Robbins, 2014). The second step adds student level data to evaluate the impact of these level 1 variables. The final step is introducing factors at higher levels of the model (King et al., 2012; Lee, 2000). From here data can be interpreted, models adjusted, and covariance and impact analyzed for factors at all levels.

3.5.3 Potential Issues

To have adequate power, HLM requires large sample sizes. Level 1 effects are especially sensitive to the sample size. Higher-level effects are greatly impacted by increases in the number of groups, but not the numbers within the groups themselves. Also, HLM is only able to handle missing data at level 1. However, in this study, level 1 is the only area in which data are missing (Hoffman, 1997). Additional issues could arise: 1) Data gathering from all entities (PLTW, IDOE, DWD, ICHE) because there are proprietary data that will require agreements; 2) the ability to control for extraneous variables that might impact the transition from high school to university and; 3) missing student level data at the higher education level.

CHAPTER 4. PRESENTATION OF DATA

4.1 Handling of Missing Data

For a case to be used on any level of an HLM model, it must have data for all of the variables being used within the model. There are two primary times in which HLM can be setup to remove missing level 1 data. One is during the creation of the initial model file containing the potential variables and the other is during the beginning of the analysis. In each instance, level 1 cases were removed from the dataset that was used for the analysis if there were missing data within any variables in the model file that were used for the analysis. This first technique for managing missing level 1 data were used throughout all analyses (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2011). The dataset was also constrained to schools for which all level 2 and level 3 data were available. The level 3 data were primarily acquired from 2010 census data. The only census data available were for school districts with defined boundaries. Hence, the level 3 data were confined to only public, non-charter, school districts and their associate schools. This was because private, charter, and parochial schools do not have defined geographic boundaries within which they draw their students.

4.2 Data Analysis

Part of the process in understanding the role of mitigating factors in this process is understanding what, if any, differences exist between schools that adopted PLTW and those that did not. Table 4.1 contains the maximum and minimum values for the all of the level 3 school districts (N=292) used in the evaluation. Because some school districts had both PLTW and non-PLTW schools, level 3 data were not broken down into these categories. Additionally, specific district level numbers were not available so it was not possible to calculate an accurate mean. Instead the minimum and maximum values were included.

Table 4.1 *2010 Public School District Data*

	Minimum	Maximum
Average Household Size	2.1	3.76
Percent Owner Occupied Housing	36.37%	96.08%
Median Home Value	$67,600	$327,500
Percent non-white students	0.00%	92.22%
Per Capita Income	$13,850	$57,400
Percent Population with at Least H.S. Diploma	7.00%	45.00%
Percent Population with at Least Bachelor's degree	1.00%	18.00%

Table 4.2 contains demographic information for all schools (N=348), schools offering PLTW (N=233), and schools that do not offer PLTW (N=115), which were used in this analysis. Of the schools offering PLTW, 181 offered PLTW Engineering courses only, five offered PLTW Biomedical courses only, and 47 offered both PLTW Engineering courses and PLTW Biomedical courses.

Table 4.2 *2010 Public School Sample Population Demographics*

	All Public Schools	PLTW Schools	Non-PLTW Schools
School is Classified as Rural	43%	42.9%	43.5%
Average Total Enrollment of School	943.73	1035.57	757.65
Free and Reduced Lunch Rate	37.0%	36.09%	40.62%
Percent of students who are non-white	25.0%	23.36%	28.34%
2010 School Attendance Rate	95.0%	95.58%	95.0%

Table 4.3 provides school level information for which there were no student level data available to calculate a mean value. Instead the minimum and maximum values for both non-PLTW schools and PLTW schools are provided.

Table 4.3 *2010 Public Schools Sample Population Minimum and Maximum*

	Non-PLTW Schools		PLTW Schools	
	Minimum	Maximum	Minimum	Maximum
Percent Grads taking AP exam	0	56.25%	0	62.69%
Percent Grads Passing AP exam	0	44.18%	0	55.00%
Percent Grads Taking SAT	N/A	89.43%	10.58%	91.87%
Average Composite Math and Verbal SAT Score	N/A	1147.25	938.49	1231.50

A two-level model was used to see what, if any, district and community level factors predict a school offering PLTW. For this model, level 1 data consisted of school level data and level 2 data consisted of district and community level data. The first step of the process is to run an unconditional model. An unconditional model can be used to determine if a multilevel model is necessary or if a simple regression can be used by running an analysis using only the dependent variable and the two levels of analysis (Gelman & Hill, 2007; Lee, 2000). For this analysis the outcome variable, if a school offered PLTW or not, was dichotomous, where 0 represented a school that did not offer PLTW and 1 represented schools offering any PLTW courses. Because of the dichotomous outcome variable, use of a Bernoulli HLM2 analysis is appropriate (Raudenbush et al., 2011). Results from the unconditional model can be found in Table 4.4. The reliability estimate was 0.109 and $p < 0.001$ which means that a multi-level model is appropriate for this analysis.

Table 4.4 *Null Analysis population-average model with robust standards errors for adopting PLTW*

Fixed Effect	Coefficient	Standard Error	t-ratio	Approx *d.f.*	p-value	Reliability Estimate
For INTRCPT1, β_0 INTRCPT2, γ_{00}	.711071	.120900	5.881	289	<0.001	0.109

Individual analyses were run for each level 1 and level 2 variable to determine their impact on the dependent variable, a school adopting PLTW. Table 4.5 shows the model and findings of each level 1 variable model. From each of these models, only the school's average SAT composite score for mathematics and English and the percent of the population that was non-white were statistically significant.

Table 4.5 *Individual Level 1 Independent Variable Models*

Variable	Mixed Model Equation	p-Value	Odds Ratio
Enrollment	$\eta_{ij} = \gamma_{00} + \gamma_{10}*ENROLL00_{ij} + u_{0j}$	.054	
School is Rural	$\eta_{ij} = \gamma_{00} + \gamma_{10}*IS\_RURAL_{ij} + u_{0j}$	.895	
SAT Avg Comp Score	$\eta_{ij} = \gamma_{00} + \gamma_{10}*AVGCOMPO_{ij} + u_{0j}$	<.001	1.007534
Free & Red Lunch Percent	$\eta_{ij} = \gamma_{00} + \gamma_{10}*FREE\_RED_{ij} + u_{0j}$	.189	
Non-white Percentage	$\eta_{ij} = \gamma_{00} + \gamma_{10}*PCT\_URM_{ij} + u_{0j}$	<.001	0.027675

Table 4.6 shows the models, p-values, odds ratio, and confidence intervals for each level 2 variable. The only statistically significant variables were the percent of the population with a high school diploma and the percent of the population with a bachelor's degree and above.

Table 4.6 *Individual Level 2 Independent Variable Models*

Variable	Mixed Model Equation	p-Value	Odds Ratio
Per Capita Income	$\eta_{ij} = \gamma_{00} + \gamma_{01} {*} PERCAPIN_j + u_{0j}$	.093	
Percent Owner Occupied Housing	$\eta_{ij} = \gamma_{00} + \gamma_{01} {*} PEROOH_j + u_{0jj}$	.225	
Median Home Value	$\eta_{ij} = \gamma_{00} + \gamma_{01} {*} MDNVALHO_j + u_{0j}$	.210	
Percent HS Diploma and Above	$\eta_{ij} = \gamma_{00} + \gamma_{01} {*} PERABVHS_j + u_{0j}$	.048	104.98 (1.034, 10657.031)
Percent BS and Above	$\eta_{ij} = \gamma_{00} + \gamma_{01} {*} PERBS_j + u_{0j}$	.031	439479 (3.315, 58262756575. 017)
Percent non-White Students	$\eta_{ij} = \gamma_{00} + \gamma_{01} {*} PERUMN_j + u_{0j}$	.650	
Per Grads Taking AP exam	$\eta_{ij} = \gamma_{00} + \gamma_{10} {*} GRADTOOK_{ij} + u_{0j}$	.348	

Because moderate to strong correlations of variables can result in an issue with singularity, causing the HLM analysis to error out of the analysis, a Pearson Correlation was run to evaluate the interconnectivity of variables within and between each level of the analysis. This correlation table can be found in the Appendix. Several moderate to strong correlations were found between variables at each level. For example, at level 1, a school's graduation rate had a moderately positive correlation with attendance rate (OR=.573, p<.001) and average composite math and verbal scores on the SAT (r=.408, p<.001). It also negatively correlated with the free and reduced lunch rate (r=-.600, p<.001) and the percentage of non-white students (r=-.412, p<.001). Additional moderate correlations were found between the percentage of students taking and passing AP exams.

For level 2 variables, there were strong positive correlations between educational attainment and per capita income (r >.77, p<.001), educational attainment and median home value (r > .59, p<.001), and median home value and per capita income (r=.825, p = .000). There were also strong negative correlations between percentage of non-white students and percentage of owner occupied housing (r= -.655, p = .000). Strong between level correlations focused primarily on school free and reduced lunch rate. It had a strong negative correlation with percent owner occupied housing and (r = - .622, p = .000), median home value (r= -.643, p<.001), and per capita income (r= - .622, p =.000). However, school percentage of non-white students had a strong positive correlation to the district level of non-white students (r= .920, p =.000) and a strong negative correlation to percent owner occupied housing (r= .688, p < .000).

Table 4.7 *Different Models for Predicting a School adopts PLTW*

Mixed Model Equation	Variable Significance	Reliability Estimates
$\eta_{ij} = \gamma_{00} + \gamma_{10}*IS\_RURAL_{ij} + \gamma_{20}*ATTENDAN_{ij} + \gamma_{30}*GRADPASS_{ij} + \gamma_{40}*AVGCOMPO_{ij} + \gamma_{50}*FREE\_RED_{ij} + \gamma_{60}*ENROLL00_{ij} + \gamma_{70}*PCT\_URM_{ij} + u_{0j}$	PCT_URM (p = .040)	.121
$\eta_{ij} = \gamma_{00} + \gamma_{01}*PERABVHS_{j} + \gamma_{10}*IS\_RURAL_{ij} + \gamma_{20}*FREE\_RED_{ij} + \gamma_{30}*ENROLL00_{ij} + \gamma_{40}*PCT\_URM_{ij} + u_{0j}$	PERABVHS (p = .035) PCT_URM (p < .001)	.127
$\eta_{ij} = \gamma_{00} + \gamma_{01}*PERABVHS_{j} + \gamma_{10}*IS\_RURAL_{ij} + \gamma_{20}*GRADTOOK_{ij} + \gamma_{30}*FREE\_RED_{ij} + \gamma_{40}*ENROLL00_{ij} + \gamma_{50}*PCT\_URM_{ij} + \gamma_{60}*ATTEND00_{ij} + u_{0j}$	PERABVHS (p = .035) PCT_URM (p < .001)	.128
$\eta_{ij} = \gamma_{00} + \gamma_{01}*PERABVHS_{j} + \gamma_{10}*PCT\_URM_{ij} + u_{0j}$	PERABVHS (p = .050)	.120
$\eta_{ij} = \gamma_{00} + \gamma_{01}*PERABVHS_{j} + \gamma_{10}*GRADUATE_{ij} + \gamma_{20}*FREE\_RED_{ij} + \gamma_{30}*ENROLL00_{ij} + \gamma_{40}*PCT\_URM_{ij} + u_{0j}$	PERABVHS (p = .047) PCT_URM (p < .001)	.124
$\eta_{ij} = \gamma_{00} + \gamma_{01}*PERABVHS_{j} + \gamma_{10}*IS\_RURAL_{ij} + \gamma_{20}*GRADPASS_{ij} + \gamma_{30}*FREE\_RED_{ij} + \gamma_{40}*ENROLL00_{ij} + \gamma_{50}*PCT\_URM_{ij} + u_{0j}$	PERABVHS (p = .035) PCT_URM (p < .001)	.127
$\eta_{ij} = \gamma_{00} + \gamma_{01}*PERABVHS_{j} + \gamma_{10}*AVGCOMPO_{ij} + \gamma_{20}*PCT\_URM_{ij} + u_{0j}$	PERABVHS (p = .046) AVGCOMP (p = .005)	.124

Based upon these strong correlations, only one of the three educational attainments (HS+, Associates+, BS+) and school free and reduced lunch rate could be used in a model to account for educational and economic attainment variables. Based upon the correlation data, multiple models were run integrating other variables to create the best overall model (see Table 4.7).

Table 4.8 *Final Estimations of Fixed Effects for Model Used for Evaluating if a School Adopted PLTW*

Variable Description	p-Value	Odds Ratio	Confidence Interval
Percent of Population with a High School Diploma or Above	.035	251.62	(1.484, 42672.554)
If the School is Rural	.457		
Percent of Graduates who took the SAT	.218		
Percent of School who is eligible for Free or Reduced Lunch	.220		
School Enrollment	.119		
Percent of the students who are non-white	<.001	.014	(.002, .119)
School attendance rate	.026	3474528.98	(6.622, 1823026158183.617)

The selection of a final model was based upon the reliability outcomes, p-values, and odds ratios using the final estimation of fixed effects. The final model selected was $\eta_{ij} = \gamma_{00} + \gamma_{01}*PERABVHS_j + \gamma_{10}*IS\_RURAL_{ij} + \gamma_{20}*GRADUATE_{ij} + \gamma_{30}*FREE\_RED_{ij} + \gamma_{40}*ENROLL00_{ij} + \gamma_{50}*PCT\_URM_{ij} + \gamma_{60}*ATTEND00_{ij} + u_{0j}$. Table 4.8 provides the final estimation of fixed effects using the population-average model with robust standard errors. This is the same type of final estimations used throughout this research. In this model, percent of the population with a high school degree or above, percent of the students who are non-white, and the school attendance rate are all significant. This means they are significant variables in a school adopting PLTW. However, both high school degree and above along with school attendance rate are not precise in their odds ratios.

4.2.1 Hypothesis 1

H_a: Attending a school that offers PLTW will increase the likelihood of students majoring in a post-secondary STEM program. This odds ratio will be greater if they have taken PLTW courses.

H_0: Attending a school that offers PLTW will not increase the likelihood of students majoring in a post-secondary STEM program. This odds ratio will be greater if they have taken PLTW courses.

When controlling for students who took a PLTW course, attending a school that offers PLTW did not increase the likelihood of students majoring in STEM. We therefore cannot reject the null hypothesis. For this analysis, the dependent variable was if a student majored in STEM. This was a dichotomous variable coded as 0 (anyone who did not have a major in a STEM field during their first semester of higher education) and 1 (their major the first semester of higher education was in a STEM field). Three levels of data were used, where level 1 were student level data (N=55612), level 2 were school data (N=346), and level 3 were district/community level data (N=289). Table 4.9 provides basic information about the PLTW schools and the non-PLTW schools.

Table 4.9 *Basic descriptive statistics of PLTW schools and non-PLTW schools*

Descriptive	PLTW Schools	Non-PLTW Schools
Number of Schools	233	115
Percentage of Schools that are rural	42.9	43.5
Maximum Enrollment	3632	4389
Minimum Enrollment	171	53
Average Enrollment	1035	758

An initial unconditional analysis was run to determine if a three level model was appropriate. Because of the dichotomous outcome variable, use of a Bernoulli HLM3 analysis is appropriate for all analyses using the variable of STEM Major as the outcome variable (Raudenbush et al., 2011). The p-value for this unconditional model was $p < .001$ indicating that the three level model was appropriate (Lee, 2000). A model was then run including the dichotomous variable PLTWSCHL [school offers PTLW (1) or a school does not offer PLTW (0)]. The equation of this model is $\eta_{ijk} = \gamma_{000} + \gamma_{010}$*ISPLTWSC$_{jk}$+ $r_{0jk} + u_{00k}$. The results of this model showed that students attending a PTLW school were more likely to major in STEM than students at a non PLTW School (p < .001, OR= 1.28). Further investigation was done to determine if PLTW students solely accounted for this difference. To determine this, another model was run to include and control for PLTW students. The results of this model, $\eta_{ijk} = \gamma_{000} + \gamma_{010}$*ISPLTWSC$_{jk}$ + γ_{100}*$ISPLTW_{ijk}$+ r_{0jk} + $u_{00k},$ were that PLTW students were more likely to major in STEM than non-PLTW students (p < .001, OR= 4.66) and attending a PLTW school was not significant (p = .672).

New models were created to further investigate the differences in majoring in STEM. Models were setup to compare PLTW students (N=4032) to non-PLTW students (N=37774) at their school, PLTW students to students at non-PLTW schools (N=13806) and non-PLTW students at PLTW schools to students at non-PLTW schools. Table 4.10 shows basic information about each of these groups of students.

Table 4.10 *Basic descriptive statistics of student groups*

Descriptive	PLTW Students	Non-PLTW Students at PLTW Schools	Non-PLTW School Students
Percent non-white	18.5%	14.6%	13.7%
Percent Eligible for Free and Reduced Lunch	29.4%	26.5%	20.8%
Percent Male	48.5%	45.2%	46.5%
Percent Honors Diploma	29.6%	29.7%	34.8%
Average ISTEP+ Math Score	570.64 SD = 71.412	574.32 SD = 68.215	600.38 SD = 6.234
Average ISTEP+ ELA Score	549.14 SD = 49.304	552.83 SD = 48.970	559.44 SD = 43.027

The finding from these three models was a statistically significant difference on majoring in STEM between PLTW students and their non-PLTW peers at the same schools (p<.001, OR=2.74) and PLTW students and students at non-PLTW schools (p<.001, OR=3.30). There was no statistical difference between non-PLTW students at PLTW schools and students at non-PLTW schools (p=.852).

4.2.2 Hypothesis 2

H_a: Attending a school that offers PLTW will increase the likelihood that a student will persist from his/her freshman to sophomore year of college.

H_o: Attending a school that offers PLTW will not increase the likelihood that a student will persist from his/her freshman to sophomore year of college.

Attending a school that offers PLTW was not a significant predictor for persisting from freshman to sophomore year of college. Therefore the null hypothesis cannot be rejected. For this analysis the dependent variable was if a student persisted from his/her freshman to sophomore years of college. This was a dichotomous variable that was coded as 0 (anyone who did not continue after their freshman year) and 1 (anyone who completed the first semester of their sophomore year). Three levels of data were used, where level 1 was student level data (N=28956), level 2 was school data (N=348), and level 3 data was district/community level data (N=289). Table 4.11 provides basic information about the PLTW schools and the non-PLTW schools.

Table 4.11 *Basic descriptive statistics of PLTW schools and non-PLTW schools*

Descriptive	PLTW Schools	Non-PLTW Schools
Number of Schools	233	115
Percentage of Schools that are rural	42.9	43.5
Maximum Enrollment	3632	4389
Minimum Enrollment	171	53
Average Enrollment	1035	758
Number of Students in Analysis	21844	7112

An initial unconditional analysis was run to determine if a three level model was appropriate. The p-value for this unconditional model was $p < .001$ indicating that the three level model was appropriate (Lee, 2000). A model was then run including the dichotomous variable providing if a school had PTLW (1) or not (0). The equation of this model is $\eta_{ijk} = \gamma_{000} + \gamma_{010}$*ISPLTWSC$_{jk}$+ $r_{0jk} + u_{00k}$. Based upon the outcomes of this model, it was found that students attending a PTLW school were not more likely to persist from their freshman to sophomore years of post-secondary education ($p = .438$).

4.2.3 Hypothesis 3

H_a: The factors that are statistically significant for majoring in STEM will be different for PLTW schools and non-PLTW schools. They will also be different for PLTW students.

H_o: The factors that are statistically significant for majoring in STEM will not be different for PLTW schools and non-PLTW schools. They will also not be different for PLTW students.

The variable, if a student was eligible for free and reduced lunch, was marginally significant for predicting majoring in STEM for students attending a school that offers PLTW ($p = .053$) but not for students attending a school that did not offer PLTW. ISTEP+ ELA score and Gender were not significant for students who took a PLTW course but was for the overall student population at a school offering PLTW and students at schools that did not offer PLTW. We can reject the null hypothesis and accept the alternative hypothesis.

For this analysis the first step was to determine which variables would be used in the comparisons. The level 1 variables were selected based upon a previous analyses run on these data (Pike & Robbins, 2014). This previous analysis also used a more limited set of level 2 variables. The previous analysis did not find any of the level 2 variables to be significant. Table 4.12 shows the findings from multilevel models run using each level 2 variable individually as a predictor of majoring in STEM.

Table 4.12 *Level 2 Variables on Majoring in STEM*

Variable Description	Mixed Model Equation	p-Value	Odds Ratio
Percent of Graduates who took SAT	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*GRADUATE$_{jk}$+ r_{0jk} +u_{00k}	<.001	5.45 (2.345, 12.664)
Percent of School Eligible for Free and Reduced Lunch Status	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*FREE_RED$_{jk}$+ r_{0jk} + u_{00k}	<.001	.19 (.076, .452)
School Enrollment	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*ENROLL00$_{jk}$+ r_{0jk} + u_{00k}	.075	
Percent of students who are non-white	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*PCT_URM$_{jk}$+ r_{0jk} + u_{00k}	<.001	.34 (.204, .581)
School Attendance Rate	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*ATTEND00$_{jk}$+ r_{0jk} + u_{00k}	.068	
Is the School Rural	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*IS_RURAL$_{jk}$+ r_{0jk} + u_{00k}	<.001	.82 (.728, .918)
Percent of Graduates Passing the SAT	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*GRADPASS$_{jk}$+ r_{0jk} + u_{00k}	<.001	22.27 (4.085, 121.451)
Average Composite Score on SAT	$\eta_{ijk} = \gamma_{000} + \gamma_{010}$*AVGCOMPO$_{jk}$+ r_{0jk} + u_{00k}	<.001	1.0037 (1.002, 1.005)

When controlling for other level 1 variables, percent of students who were non-white and percent of students eligible for free and reduced lunch status were no longer statistically significant. This left the three variables related to the SAT exam. Because of the high correlation between these three variables only one could be used in the model at a time. Of these, the percent of graduates who took the SAT was less impacted when controlling for the level 1 and level 3 variables and was used in this model and all future STEM major related models.

Table 4.13 *Variable Predicting STEM Majors with High School Diploma Variable*

Variable	PLTW School		Non-PLTW Schools		PLTW Students	
Random Coefficient Reliability Est.	Level 1 - .155 Level 2 - .341		Level 1 - .000 Level 2 - .202		Level 1 - .136 Level 2 - .208	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with High School Diploma or Above	.002	7.42 (2.139, 25.742)	.034	5.26 (1.140, 24.298)	.003	19.10 (2.778, 131.306)
Percent of Graduates taking SAT	.330		.054		.563	
Gender	<.001	2.77 (2.485, 3.083)	<.001	3.33 (2.873, 3.868)	.663	
Non-White Student	.065		.212		<.001	2.56 (1.805, 3.630)
Eligible for Free or Reduced Lunch Program	.053		.384		.045	.79 (.632, .995)
Received a Core 40 Diploma	<.001	1.97 (1.610, 2.402)	<.001	2.29 (1.717, 3.062)	<.001	2.94 (1.947, 4.454)
Received an Honors Diploma	<.001	4.93 (3.971, 6.128	<.001	6.25 (4.813, 8.122)	<.001	5.73 (3.591, 9.153)
8th Grade ISTEP+ Math Score (divided by 100)	<.001	1.08 (1.065, 1.087)	<.001	1.07 (1.059, 1.089)	<.001	1.07 (1.054, 1.097)
8th Grade ISTEP+ ELA Score (divided by 100)	.012	0.98 (.966, .996)	.012	0.97 (.950, .994)	.80	

For the level 3 variables, the percent of the population with a high school diploma or above, the percent of the population with a bachelor's degree or above, and the per capita income of the population all provide interesting outcomes when included separately within the model. Therefore to answer this question, three models were run changing the level 3 variable in each model. Table 4.13, uses percent of population with a high school diploma or above as the level 3 variable and provides the outcomes for the model run on all students at a PLTW school, all students at non-PLTW schools, and

PLTW students. The equation of these models was $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERABVHS$_k$ + γ_{010}*GRADUATE$_{jk}$ + γ_{100}*$GENDER_{ijk}$ + γ_{200}*URM_STDN_{ijk} + γ_{300}*LOW_SES_{ijk} + γ_{400}*$CORE40_{ijk}$ + γ_{500}*$HONORS_{ijk}$ + γ_{600}*$MATH0_{ijk}$ + γ_{700}*$ELA0_{ijk}$ + r_{0jk} + u_{00k}. All variables that were statistically significant predictors of majoring in STEM for a PLTW school were also significant for non-PLTW School students. However, unlike these previous two groups, for a PLTW student, being non-white and not being eligible for free or reduced lunch were significant while being male and 8th Grade ISTEP+ ELA scores were not.

Table 4.14 *Variable Predicting STEM Majors with Bachelor's Degree Variable*

Variable Random Coefficient Reliability Est.	PLTW School Level 1- .153 Level 2-.343		Non-PLTW Schools Level 1 - .000 Level 2 - .206		PLTW Students Level 1 - .138 Level 2- .212	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with Bachelor's Degree or Above	<.001	52.94 (5.819, 481.583)	.053		.009	140.19 (3.390, 5797.379)
Percent of Graduates taking SAT	.324		.059		.550	
Gender	<.001	2.77 (2.486, 3.081)	<.001	3.33 (2.872, 3.869)	.652	
Non-White Student	.072		.176		<.001	2.56 (1.806, 3.629)
Eligible for Free or Reduced Lunch Program	.049	.89 (.786, .999)	.431		.036	.79 (.628, .985)
Received a Core 40 Diploma	<.001	1.96 (1.607, 2.398)	<.001	2.30 (1.717, 3.071)	<.001	2.94 (1.952, 4.440)
Received an Honors Diploma	<.001	4.91 (3.960, 6.091)	<.001	6.27 (4.815, 8.165)	<.001	5.71 (3.587, 9.082)
8th Grade ISTEP+ Math Score (divided by 100)	<.001	1.08 (1.065, 1.087)	<.001	1.07 (1.059, 1.089)	<.001	1.08 (1.054, 1.097)
8th Grade ISTEP+ ELA Score (divide by 100)	.011	.98 (.966, .996)	.011	.97 (.950, .994)	.792	

Table 4.14 shows the same types of data as Table 4.13 but with a similar model where the level 3 variable has been changed from percent of the population with a high school diploma or above to the percent of the population with a bachelor's degree or above. The equation of these models is $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERBS$_k$ + γ_{010}*GRADUATE$_{jk}$ + γ_{100}*$GENDER_{ijk}$ + γ_{200}*URM_STDN_{ijk} + γ_{300}*LOW_SES_{ijk} + γ_{400}*$CORE40_{ijk}$ + γ_{500}*$HONORS_{ijk}$ + γ_{600}*$MATH0_{ijk}$ + γ_{700}*$ELA0_{ijk}$ + r_{0jk} + u_{00k}. The variables that were significant in this model for PLTW school students and non-PLTW school students were almost identical. The exceptions are the percent of the population with a Bachelor's degree and if a student is eligible for free and reduced lunch. They were significant for PLTW School students but not for their non-PLTW school peers. PLTW students are different from their school peers in that gender and ISTEP+ ELA score are not significant for them, while being white was significant.

The data in Table 4.15 show the output to models similar to the tables above but for this model Per Capita income is the level 3 variable being used. The equation for these models was $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERCAPIN$_k$ + γ_{010}*GRADUATE$_{jk}$ + γ_{100}*$GENDER_{ijk}$ + γ_{200}*URM_STDN_{ijk}+ γ_{300}*LOW_SES_{ijk} + γ_{400}*$CORE40_{ijk}$ + γ_{500}*$HONORS_{ijk}$ + γ_{600}*$MATH0_{ijk}$ + γ_{700}*$ELA0_{ijk}$ + r_{0jk} + u_{00k}. The significant variables for PLTW school students and non-PLTW school students were again almost identical. One exception was per capita income, which was significant for non-PLTW school students and not for PLTW School students. Also, eligibility for free and reduced lunch was significant for PLTW School students and not for non-PLTW school students. PLTW students are different from their school peers in that gender and ISTEP+ ELA score were not significant but being white was significant.

Table 4.15 *Variable Predicting STEM Majors with Per Capita Income*

Variable Random Coefficient Reliability Est.	PLTW School Level 1 - .173 Level 2 - .344		Non-PLTW Schools Level 1 - .000 Level 2 – 1.82		PLTW Students Level 1 - .270 Level 2 - .066	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Per Capita Income	.054		<.001	1.000019 (1.000, 1.000)	.001 (1.000, 1.000)	1.000033
Percent of Graduates taking SAT	.316		.064		.514	
Gender	<.001	2.77 (2.481, 3.087)	<.001	3.330 (2.871, 3.864)	.650	
Non-White Student	.053		.125		<.001	2.59 (1.823, 3.672)
Eligible for Free or Reduced Lunch Program	.047	.88 (.781, .998)	.378		.052	
Received a Core 40 Diploma	<.001	1.97 (1.612, 2.411)	<.001	2.284 (1.703, 3.064	<.001	2.95 (1.965, 4.430)
Received an Honors Diploma	<.001	4.95 (3.982, 6.163)	<.001	6.190 (4.730, 8.100)	<.001	5.74 (3.616, 9.108)
8th Grade ISTEP+ Math Score (divided by 100)	<.001	1.08 (1.064, 1.087)	<.001	1.074 (1.060, 1.089)	<.001	1.08 (1.055, 1.097)
8th Grade ISTEP+ ELA Score (divide by 100)	.012	.98 (.965, .996)	.013	.972 (.951, .994)	.786	

These three models have shown that no matter if a student attends a school that offers PLTW, one that does not offer PLTW or takes a PLTW course, the percent of the population with a high school diploma and above, receiving a Core 40 diploma, receiving an Honors Diploma, 8th grade ISTEP+ mathematics scores were all predictors of majoring in STEM. Higher ISTEP+ ELA scores and gender did not predict majoring in STEM for PLTW students but did predict majoring in STEM for students attending schools that did not offer PLTW and for the overall student population of schools that offered PLTW. Being white was a predictor of majoring in STEM for PLTW students but not for the other two groups.

4.2.4 Hypothesis 4

H$_a$: The factors for college persistence will differ for students at PTLW schools, students at non-PLTW schools, and PLTW students.

H$_o$: The factors for college persistence will not differ for students at PTLW schools, students at non-PLTW schools, and PLTW students.

The percent of graduates taking the SAT, being non-white, and ISTEP+ ELA Score were all significant predictors for persistence for students attending a school that offered PLTW and for students attending a school that did not offer PTLW. It was not significant for students who took a PLTW course. We can therefore reject the null hypothesis and accept the alternative. For this analysis the first step was to determine which variables would be used in the comparisons. The selection of variables for the model was based upon utilizing the variables that were statistically significant or enhanced the overall descriptive value of the model based upon an analysis of the entire sample. The selection of level 1 variables was based upon a previous analyses run on these data (Pike & Robbins, 2014). This previous analysis also used a more limited set of level 2 variables. The previous analysis did not find any of the level 2 variables to be significant. Table 4.16 shows the findings from multilevel analyses using each level 2 variable individually as a predictor of persisting from freshman to sophomore year.

When controlling for its level 1 counterpart, percent of students eligible for free and reduced lunch status was no longer statistically significant. Also, when controlling for level 1 factors, attendance rate was also no longer significant ($p=.938$) nor did it add to the overall reliability of the model. This left the three variables related to the SAT exam and the school attendance rate. Because of the high correlation between the three SAT variables, only one could be used in a model at a time. Of these, the percent of graduates who took the SAT was less impacted when controlling for other level 1 and level 3 variables. Therefore it was selected for use in the model.

Table 4.16 *Level 2 Variables on Persistence from Freshman to Sophomore Year*

Variable Description	p-Value	Odds Ratio and Confidence Interval
Percent of Graduates who took SAT	<.001	6.78 (3.075, 14.945)
Percent of School Eligible for Free and Reduced Lunch Status	<.001	0.14 (.063, .312)
School Enrollment	.111	
Percent of students who are non-white	.274	
School Attendance Rate	<.001	4673.09 (90.832, 240420.505)
Is the School Rural	.467	
Percent of Graduates Passing the SAT	<.001	54.84 (12.110, 248.393)
Average Composite Score on SAT	<.001	1.004 (1.002, 1.005)

For the level 3 variables, the percent of the population with a high school diploma or above, the percent of the population with a bachelor's degree or above, and the per capita income of the population, all provide interesting outcomes when included separately within the model. Therefore to better answer this question, three models were run changing the level 3 variable in each model. Table 4.17 shows the outcomes of the first model using the level 3 variable percent of population with a high school diploma or above and shows the p-values and odds ratios for this model for all students at a PLTW school, all students at non-PLTW schools, and PLTW students. The model for these analyses was $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERABVHS$_k$ + γ_{010}*GRADUATE$_{jk}$ + γ_{100}*$GENDER_{ijk}$ +

γ_{200}*URM_STDN_{ijk} + γ_{300}*LOW_SES_{ijk} + γ_{400}*$CORE40_{ijk}$ + γ_{500}*$HONORS_{ijk}$ + γ_{600}*$MATH0_{ijk}$ + γ_{700}*$ELA0_{ijk}$ + r_{0jk} + u_{00k}. The variables that were significant for PLTW and non-PLTW schools were identical except Gender was significant for PLTW schools and not for non-PLTW Schools. PLTW students varied from their same school peers in that being white, the percent of the students taking the SAT, and ISTEP+ ELA scores were not significant.

Table 4.17 *Variables Predicting Persistence with High School Diploma Variable*

Variable Random Coefficient Reliability Est.	PLTW School Level 1 - .312 Level 2 - .328		Non-PLTW Schools Level 1 - .041 Level 2 - .398		PLTW Students Level 1 - .000 Level 2 - .130	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with High School Diploma or Above	<.001	12.31 (5.119, 29.621)	.011	7.4 (1.606, 34.110)	.008	13.12 (1.955, 88.095)
Percent of Graduates taking SAT	.004	2.92 (1.459, 5.861)	<.001	15.47 (7.393, 32.388)	.167	
Gender	.028	.928 (.870, .992)	.534		.032	.75 (.576, .976)
Non-White Student	<.001	.76 (.670, .853)	.001	.70 (.564, .868)	.092	
Eligible for Free or Reduced Lunch Program	<.001	.75 (.687, .819)	.016	.79 (.648, .957)	<.001	.63 (.504, .780)
Received a Core 40 Diploma	<.001	3.95 (3.453, 4.511)	<.001	3.77 (2.949, 4.811)	<.001	3.00 (2.099, 4.301)
Received an Honors Diploma	<.001	13.65 (11.521, 16.180)	<.001	11.23 (8.545, 14.766)	<.001	9.56 (6.286, 14.544)
8th Grade ISTEP+ Math Score (divided by 100)	.862		.111		.574	
8th Grade ISTEP+ ELA Score (divided by 100)	<.001	1.03 (1.015, 1.039)	.002	1.04 (1.013, 1.060)	.118	

Table 4.18 shows the same types of data as above with a similar model where the level 3 variable has been changed from percent of the population with a high school

diploma or above to the percent of the population with a bachelor's degree or above. The equation of this model was $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERBS$_k$ + γ_{010}*GRADUATE$_{jk}$ + γ_{100}*$GENDER_{ijk}$+ γ_{200}*URM_STDN_{ijk} + γ_{300}*LOW_SES_{ijk} + γ_{400}*$CORE40_{ijk}$ + γ_{500}*$HONORS_{ijk}$ + γ_{600}*$MATH0_{ijk}$ + γ_{700}*$ELA0_{ijk}$ + r_{0jk} + u_{00k}. The variables that were significant for PLTW and non-PLTW schools were identical except Gender was significant for PLTW schools and not for non-PLTW Schools. PLTW students varied from their same school peers in that being white, percent of the students taking the SAT, and ISTEP+ ELA scores were not significant.

Table 4.18 *Variables Predicting Persistence with Bachelor's Degree or Above*

Variable Random Coefficient Reliability Est.	PLTW School Level 1 - .310 Level 2 - .325		Non-PLTW Schools Level 1 - .026 Level 2 - .376		PLTW Students Level 1 - .000 Level 2 - .130	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with Bachelor's Degree or Above	<.001	187.05 (30.533, 1145.950)	<.001	270.50 (35.838, 2041.746)	.012	109.76 (2.84, 4241.624)
Percent of Graduates taking SAT	.004	2.92 (1.445, 5.894)	<.001	15.54 (7.307, 33.044)	.156	
Gender	.027	.93 (.869, .992)	.512		.032	.75 (.580, .976)
Non-White Student	<.001	.75 (.669, .849)	.001	.70 (.562, .867)	.084	
Eligible for Free or Reduced Lunch Program	<.001	.75 (.686, .818)	.015	.79 (.648, .955)	<.001	.62 (.500, .773)
Received a Core 40 Diploma	<.001	3.94 (3.445, 4.499)	<.001	3.76 (2.936, 4.811)	<.001	3.00 (2.096, 4.293)
Received an Honors Diploma	<.001	13.58 (11.456, 16.905)	<.001	11.18 (8.469, 14.753)	<.001	9.47 (6.238, 14.397)
8th Grade ISTEP+ Math Score (divided by 100)	.835		.109		.567	
8th Grade ISTEP+ ELA Score (divided by 100)	<.001	1.03 (1.015, 1.039)	.002	1.04 (1.013, 1.060)	.116	

The data in Table 4.19 shows the output to a model similar to the tables above but for this model Per Capita income is the level 3 variable being used. The mixed-equation of this model was $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERCAPIN$_k$ + γ_{010}*GRADUATE$_{jk}$ + γ_{100}*$GENDER_{ijk}$ + γ_{200}*URM_STDN_{ijk} + γ_{300}*LOW_SES_{ijk} + γ_{400}*$CORE40_{ijk}$ + γ_{500}*$HONORS_{ijk}$ + γ_{600}*$MATH0_{ijk}$ + γ_{700}*$ELA0_{ijk}$ + r_{0jk} + u_{00k}. The variables that were significant for PLTW and non-PLTW schools were identical except Gender was significant for PLTW schools and not for non-PLTW Schools. PLTW students varied from their same school peers in that being white, percent of the students taking the SAT, and ISTEP+ ELA scores were not significant.

Table 4.19 *Variables Predicting Persistence with Per Capita Income*

Variable Random Coefficient Reliability Est.	PLTW School Level 1 - .318 Level 2 - .288		Non-PLTW Schools Level 1 - .067 Level 2 - .280		PLTW Students Level 1 - .000 Level 2 - .122	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Per Capita Income	<.001	1.000031 (1.000, 1.000)	<.001	1.000038 (1.000, 1.000)	.002	1.000032 (1.000, 1.000)
Percent of Graduates taking SAT	.003	3.00 (1.516, 5.942)	<.001	16.62 (7.624, 36.246)	.129	
Gender	.025	.93 (.868, .991)	.477		.029	.75 (.574, .971)
Non-White Student	<.001	.76 (.678, .863)	.002	.71 (.569, .879)	.076	
Eligible for Free or Reduced Lunch Program	<.001	.75 (.690, .823)	.020	.79 (.655, .965)	<.001	.63 (.507, .788)
Received a Core 40 Diploma	<.001	3.94 (3.442, 4.511)	<.001	3.78 (2.943, 4.844)	<.001	2.99 (2.083, 4.278)
Received an Honors Diploma	<.001	13.60 (11.460, 16.151)	<.001	11.24 8.472, 14.906)	<.001	9.51 (6.244, 14.495)
8th Grade ISTEP+ Math Score (divided by 100)	.796		.096		.552	
8th Grade ISTEP+ ELA Score (divided by 100)	<.001	1.03 (1.016, 1.039)	.002	1.04 (1.013, 1.061)	.122	

As the above tables have shown the factors for persistence from freshman to sophomore year are very similar for PLTW schools and non-PLTW schools. The only difference in all three tables being gender, which is a factor for PLTW school students. PLTW students also vary from their school peers in ISTEP+ ELA score, percent of students at school taking the SAT, and being non-white which are not significant factors for them.

4.2.5 Hypothesis 5

H_a: District/community level factors (see Figure 1.1) focused on educational attainment and income/wealth will be statistically significant in impacting the likelihood PLTW students major in STEM. These factors will differ for non-PLTW students at PLTW schools and students at non-PLTW schools.

H_o: District/community level factors (see Figure 1.1) focused on educational attainment and income/wealth will not be statistically significant in impacting the likelihood PLTW students major in STEM. These factors will not differ for non-PLTW students at PLTW schools and students at non-PLTW schools.

When not controlling for other variables, per capita income ($p<.004$), percent of the population with a high school diploma or above $p<.001$), and percent of the population with a bachelor's degree or above ($p<.001$) were predictors of a student who took a PLTW course majoring in STEM. We may therefore reject the first part of the null hypothesis. Each of these variables were also significant for students attending a school offering PLTW but who did not take a PLTW course as well as students attending a school that did not offer PLTW. Percent owner occupied housing and average family size were not predictors for either of the three groups. Percent of the population that is non-white was significant for students attending a school offering PLTW but who did not take a PLTW course (p=.049) but not for students who took a PLTW course or students attending schools that do not offer PLTW. Thus we may also reject the last section of the null hypothesis and accept the alternate hypothesis in its entirety.

Table 4.20 *Level 3 Variables and PLTW Students Majoring in STEM*

Variable	PLTW Students		Non-PLTW Students at PLTW Schools		Non-PLTW Schools	
Variable and Mixed Model	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Median Home Value $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*MDNVALHO$_k$+ r_{0jk} + u_{00k}	.015	1.000004 (1.000, 1.000)	Sing		<.001	1.000005 (1.000, 1.000)
Per Capita Income $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERCAPIN$_k$+ r_{0jk} + u_{00k}	.004	1.000035 (1.000, 1.000)	<.001	1.000028 (1.000, 1.000)	<.001	1.000031 (1.000, 1.000)
Percent of Population that is non-White $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERUMN$_k$+ r_{0jk} + u_{00k}	.065		.049	1.88 (1.002, 3.541)	.600	
Percent of Population with a High School Diploma or Above $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERABVHS$_k$+ r_{0jk} + u_{00k}	<.001	32.528018 (5.836, 181.302)	<.001	24.16 (6.449, 90.514)	<.001	17.6728 (4.447, 70.235)
Percent of Population with a Bachelor's or Above $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PERBS$_k$+ r_{0jk} + u_{00k}	.<.001	666.40 (25.763, 17237.757)	<.001	1031.23762 (99.032, 10738.419)	<.001	193.7966 (20.136, 1865.171)
Percent Owner Occupied Housing $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*PEROOH$_k$+ r_{0jk} + u_{00k}	.444		.769		.095	
Average Family Size $\eta_{ijk} = \gamma_{000} + \gamma_{001}$*AVGFAMSI$_k$ + γ_{002} + r_{0jk} + u_{00k}	.188		.541		.681	

The first step in looking at how level 3 (district/community level factors) impact PLTW students majoring in STEM was to run models with STEM major as the outcome variable and using each level 3 variable as the predictor variable independently. This model was run for not only the PLTW students but also for non-PLTW students at PLTW schools and for students who attended schools that did not offer PLTW.

Without controlling for any other factors, the level 3 factors that were significant predictors of majoring in STEM were the same for PLTW students, non-PLTW students at PLTW schools, and students attending non-PLTW schools. Table 4.20 shows the findings of these models.

Hypothesis 7 will further discuss the impact and extent of impact of the three primary level 3 (district/community) level variables that were used throughout this research.

4.2.6 Hypothesis 6

H_a: For PLTW students, the odds ratios for statistically significant district/community level factors will be greater than the odds ratio of school and student level variables for majoring in STEM. The odds ratio for these factors for PLTW students will be proportionally greater for PLTW students than non-PLTW students at PLTW schools and students at non-PLTW schools.

H_o: For PLTW students, the odds ratios for statistically significant district/community level factors will be the same as the odds ratio of school and student level variables for majoring in STEM. The odds ratio for these factors for PLTW students will be proportionally equal for PLTW students, non-PLTW students at PLTW schools, and students at non-PLTW schools.

For students who have taken a PLTW course the odds ratio for the percent of the population with a high school diploma and above is 19.10 and for the percent of the population with a bachelor's degree or above it is 140.19. This means for every one percent higher of the population that has a high school diploma or above the odds are 19.10 greater that a student will major in STEM and with a bachelor's or above 140.19 times more likely to major in STEM. The next closest odds ratio on a non-dichotomous variable in both models is 1.07 and the largest odd ratio for dichotomous variables is 5.73 and 5.71. Thus we may reject the first part of the null hypothesis. Proportionally, the odds ratio for percent of the population with a high school diploma or above compared to the next highest non-dichotomous variable and the highest dichotomous variable is proportionally twice as large for students who have taken PLTW as students attending a school offering PLTW but who did not take a PLTW course and for students attending schools that do not offer PLTW. We may reject the last part of the null hypothesis and accept the alternative hypothesis.

To answer this question, the same three models (using the three different level-3 variables) were run on the data of PLTW students, students at schools that do not offer PLTW, and all students at a school that offers PLTW. Table 4.21 shows the outcomes from the analyses using the percent of the population with a high school diploma or higher. For PLTW students this level 3 variable has the largest odds ratio (OR= 19.10). However, the lower end of its confidence interval was the second highest of lower end confidence interval values. However, for the other two groups of students this level 3 variable also had the largest odds ratio but it was proportionally less when compared to the other factors than it was for PLTW students.

Table 4.21 *Variable Predicting STEM Majors with High School Diploma Variable*

Variable	PLTW School Non-PLTW Students		Non-PLTW Schools		PLTW Students	
Random Coefficient Reliability Est.	Level 1 - .159 Level 2 - .338		Level 1 - .000 Level 2 - .202		Level 1 - .136 Level 2 - .208	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with High School Diploma or Above	.002	7.44 (2.145, 25.823)	.034	5.26 (1.140, 24.298)	.003	19.10 (2.778, 131.306)
Percent of Graduates taking SAT	.329		.054		.563	
Gender	<.001	2.76 (2.484, 3.082)	<.001	3.33 (2.873, 3.868)	.663	
Non-White Student	.066		.212		<.001	2.56 (1.805, 3.630)
Eligible for Free or Reduced Lunch Program	.053	.89 (.786, 1.002)	.384		.045	.79 (.632, .995)
Received a Core 40 Diploma	<.001	1.97 (1.610, 2.403)	<.001	2.29 (1.717, 3.062)	<.001	2.94 (1.947, 4.454)
Received an Honors Diploma	<.001	4.93 (3.970, 6.127)	<.001	6.25 (4.813, 8.122)	<.001	5.73 (3.591, 9.153)
8th Grade ISTEP+ Math Score (divided by 100)	<.001	1.08 (1.065, 1.087)	<.001	1.07 (1.059, 1.089)	<.001	1.07 (1.054, 1.097)
8th Grade ISTEP+ ELA Score (divided by 100)	<.012	.98 (.966, .996)	.012	0.97 (.950, .994)	.80	

Table 4.22 runs the same type of analyses as Table 4.21 except the level 3 variable is now the percent of the population with a bachelor's degree or above. For PLTW students this level 3 variable has the highest odds ratio (140.19). However, it also has a very large confidence interval (3.390, 5797.379) meaning that it is possible that the diploma types (Core 40 and Honors) could actually be higher. This finding is very similar to the findings for the non-PLTW students at PLTW schools with an odds ratio of 54.23

and a confidence interval of (5.979, 491.884). For non-PLTW school students this level 3 variable was not significant at the .05 level.

Table 4.22 *Variable Predicting STEM Majors with Bachelor's Degree Variable*

Variable	PLTW School Non-PLTW Students		Non-PLTW Schools		PLTW Students	
Random Coefficient Reliability Est.	Level 1- .158 Level 2- .339		Level 1 - .000 Level 2 - .206		Level 1 - .138 Level 2- .212	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with Bachelor's Degree or Above	<.001	54.23 (5.979, 491.884)	.053		.009	140.19 (3.390, 5797.379)
Percent of Graduates taking SAT	.323		.059		.550	
Gender	<.001	2.77 (2.484, 3.079)	<.001	3.33 (2.872, 3.869)	.652	
Non-White Student	.072		.176		<.001	2.56 (1.806, 3.629)
Eligible for Free or Reduced Lunch Program	.049	.89 (.786, 1.00)	.431		.036	.79 (.628, .985)
Received a Core 40 Diploma	<.001	1.96 (1.608, 2.399)	<.001	2.30 (1.717, 3.071)	<.001	2.94 (1.952, 4.440)
Received an Honors Diploma	<.001	4.91 (3.958, 6.089)	<.001	6.27 (4.815, 8.165)	<.001	5.71 (3.587, 9.082)
8^{th} Grade ISTEP+ Math Score (divided by 100)	<.001	1.08 (1.065, 1.087)	<.001	1.07 (1.059, 1.089)	<.001	1.08 (1.054, 1.097)
8^{th} Grade ISTEP+ ELA Score (divided by 100)	.012	.98 (.966, .996)	.011	.97 (.950, .994)	.792	

Table 4-23 runs the analysis using the level 3 variable per capita income. Because per capita income is a continuous variable, and has a very wide range, it could be a very significant factor in majoring in STEM. The same is true for non-PLTW students at PLTW schools and non-PLTW students. However, the initial odds ratios are significantly smaller per dollar than PLTW students compared to one another and compared to the other variables within their own analysis.

Table 4.23 *Variable Predicting STEM Majors with Per Capita Incom*e

Variable	PLTW School Non-PLTW Students		Non-PLTW Schools		PLTW Students	
Random Coefficient Reliability Est.	Level 1 - .178 Level 2 - .341		Level 1 - .000 Level 2 – 1.82		Level 1 - .270 Level 2 - .066	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Per Capita Income	.054	1.000013 (1.000, 1.000)	<.001	1.000019 (1.000, 1.000)	<.001	1.000033 (1.000, 1.000)
Percent of Graduates taking SAT	.315		.064		.514	
Gender	<.001	2.77 (2.480, 3.086)	<.001	3.330 (2.871, 3.864)	.650	
Non-White Student	.054		.125		<.001	2.59 (1.823, 3.672)
Eligible for Free or Reduced Lunch Program	.047	.88 (.781, .999)	.378		.052	
Received a Core 40 Diploma	<.001	1.97 (1.612, 2.413)	<.001	2.284 (1.703, 3.064	<.001	2.95 (1.965, 4.430)
Received an Honors Diploma	<.001	4.95 (3.980, 6.162)	<.001	6.190 (4.730, 8.100)	<.001	5.74 (3.616, 9.108)
8th Grade ISTEP+ Math Score (divided by 100)	<.001	1.08 (1.064, 1.087)	<.001	1.074 (1.060, 1.089)	<.001	1.08 (1.055, 1.097)
8th Grade ISTEP+ ELA Score (divided by 100)	.013	.98 (.965, .996)	.013	.972 (.951, .994)	.786	

While there are many similarities in the variables that impact a student from each of the three groups in majoring in STEM, there are also several differences. For example, gender and ISTEP+ ELA score are not predictors for PTLW students majoring in STEM but are for the other two groups of students. However, being non-white is a predictor for PLTW students majoring in STEM but is not a factor for the other groups. Free and reduced lunch status is a factor for non-PLTW students at PLTW schools as well as for

PLTW students (except when controlling for per-capita income) but is not for non-PLTW school students. Finally, the percent of the population with a Bachelor's degree or above is not significant for non-PLTW school students majoring in STEM but is significant for both of the PLTW school student groups.

4.2.7 Hypothesis 7

H_a: a) District/community level factors focused on educational attainment and income/wealth will be statistically significant in impacting PLTW students persisting from their freshman to sophomore year of college. b) The statistically significant factors for PLTW students will be different from the statistically significant factors for non-PLTW students at PLTW schools or students at non-PLTW schools for persisting.

H_o: a) District/community level factors focused on educational attainment and income/wealth will not be statistically significant in impacting PLTW students persisting from their freshman to sophomore year of college. b) The statistically significant factors for PLTW students will not be different from the statistically significant factors for non-PLTW students at PLTW schools and students at non-PLTW schools for persisting.

Median home value, per capita income, percent of the population with a high school diploma or above, percent of the population with a bachelor's degree or above, percent of the population that is non-white, and percent owner occupied housing were all statistically significant at the .05 level for students who took PLTW courses, students at schools who offer PLTW but did not take a PLTW course, and students attending schools that did not offer PLTW (See table 4.24). While the odds ratios were different as were the p values, the same variables were significant. Thus we may reject part A of the null hypothesis and can accept part A of the alternative hypothesis. However, we may not reject part B of the null hypothesis.

Table 4.24 *Level 3 Variables and PLTW Students Persistence*

Variable	PLTW Students		Non-PLTW Students at PLTW Schools		Non-PLTW Schools	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Median Home Value	.009	1.000004 (1.000, 1.000)	<.001	1.000007 (1.000, 1.000)	<.001	1.000007 (1.000, 1.000)
Per Capita Income	<.001	1.000035 (1.000, 1.000)	<.001	1.000042 (1.000, 1.000)	<.001	1.000049 (1.000, 1.000)
Percent of Population that is non-White	<.015	.045 (.235, .857)	<.001	.38 (.229, .638)	<.001	.32 (.206, .488)
Percent of Population with a High School Diploma or Above	.004	15.16 (2.377, 96.726)	<.001	22.12 (7.857, 62.289)	.027	7.23 (1.261, 47.383)
Percent of Population with a Bachelor's or Above	.004	227.86 (5.912, 8782.487)	<.001	1070.31 (146.815, 7802.825)	<.001	859.37 (47.097, 15680.641)
Percent Owner Occupied Housing	<.001	5.26 (2.003, 13.802)	<.001	4.43 (1.812, 10.811)	.004	7.57 (1.950, 29.257)

The first step in looking at how level 3 (district/community level factors) impact PLTW students persisting from their freshman to sophomore year of higher education was to run models with persistence as the outcome variable using each level 3 variable independently as the predictor variable. This was done for not only the PLTW students but also for non-PLTW students at PLTW schools and for students who attended schools that did not offer PLTW. When using multilevel models utilizing only individual variables, median home value, per capita income, percent of the population with a high school diploma or above, percent of the population with a bachelor's degree or above, percent of the population that is non-white, and percent owner occupied housing were predictors of persistence were predictors of persistence for students who took PLTW courses, students at PLTW schools who did not take PLTW courses, and students at schools that did not offer PLTW. Table 25 shows the findings of these models.

Hypothesis 8 will further discuss the impact and extent of impact of the three primary level 3 (district/community) level variables that were used throughout this research.

4.2.8 Hypothesis 8

H_a: For PLTW students, the odds ratios for statistically significant district/community level factors will be greater than the odds ratio of school and student level variables (see Figure 1.2) for persisting from their freshman to sophomore year of college. The odds ratio for these level 3 factors will be proportionally greater for PLTW students than non-PLTW students at PLTW schools and students at non-PLTW schools.

H_o: For PLTW students, the odds ratios for statistically significant district/community level factors will be equivalent to the odds ratio of school and student level variables for persisting from their freshman to sophomore year of college. The odds ratio for these level 3 factors will be proportionally less than or equal for PLTW students, non-PLTW students at PLTW schools, and students at non-PLTW schools.

The odds ratio for the percent of the population with a high school diploma has an odds ratio of 13.2. This is the largest odds ratio of any variable. The largest odds ratio of a dichotomous variable in this model is 9.56. The largest variable using percentage had an odds ratio of 0.63 (1.59 if recoded). The odds ratio for percent of the population with a bachelor's degree was 109.76. This was substantially larger than the odds ratio of the dichotomous variable with the greatest odds ratio of 9.47. It was also greater than odds ratio of the variable using percentages (.62 or 1.61 if recoded reversely).Thus we can reject the first part of the null hypothesis.

The proportion for the odds ratios when looking at the district level variables of percent of the population with a high school diploma and above and percent of the population with a bachelor's degree and above to the dichotomous variable with the greatest odds ratio (receiving an Honors diploma) for student who took a PLTW course (1.37, 11.59), students at PLTW schools who didn't take PLTW courses (.659, 24.195) and students attending schools that don't offer PLTW (.9, 13.69). The proportions for students who took a PLTW course are proportionally less for the model utilizing the percentage of the population with a bachelor's degree or less. Therefore we cannot reject the second part of the null hypothesis.

To answer this question, the same three models (using the 3 different level-3 variables) were run on the data of PLTW students, non-PLTW students and PLTW schools, and non-PLTW school students. Table 4.25 show the outcomes from the analyses using the percent of the population with a high school diploma or higher. For PLTW students this level 3 variable has the largest odds ratio (OR= 19.10). However, its confidence interval had the largest span (1.955, 88.095). However, for the other two groups of students this level 3 variable did not have largest odds ratio but they both also had the largest confidence intervals.

Table 4.25 *Variables Predicting Persistence with High School Diploma Variable*

Variable	PLTW School Non-PLTW Students		Non-PLTW Schools		PLTW Students	
Random Coefficient Reliability Est.	Level 1 - .311 Level 2 - .331		Level 1 - .041 Level 2 - .398		Level 1 - .000 Level 2 - .130	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with High School Diploma or Above	<.001	12.29 (5.110, 29.575)	.011	7.4 (1.606, 34.110)	.008	13.12 (1.955, 88.095)
Percent of Graduates taking SAT	.004	2.93 (1.459, 5.886)	<.001	15.47 (7.393, 32.388)	.167	
Gender	.029	.93 (.870, .992)	.534		.032	.75 (.576, .976)
Non-White Student	<.001	.76 (.670, .853)	.001	.70 (.564, .868)	.092	
Eligible for Free or Reduced Lunch Program	<.001	.75 (.687, .819)	.016	.79 (.648, .957)	<.001	.63 (.504, .780)
Received a Core 40 Diploma	<.001	3.95 (3.455, 4.513)	<.001	3.77 (2.949, 4.811)	<.001	3.00 (2.099, 4.301)
Received an Honors Diploma	<.001	13.66 (11.523, 16.183)	<.001	11.23 (8.545, 14.766)	<.001	9.56 (6.286, 14.544)
8th Grade ISTEP+ Math Score (divided by 100)	.868		.111		.574	
8th Grade ISTEP+ ELA Score (divide by 100)	<.001	1.03 (1.015, 1.039)	.002	1.04 (1.013, 1.060)	.118	

Table 4.26 runs the same type of analyses as Table 4.25 except the level 3 variable is now the percent of the population with a bachelor's degree or above. For PLTW students this level 3 variable has the highest odds ratio (109.76). However, it also has a very large confidence interval (2.84, 4241.624) meaning that it is possible that the diploma types (Core 40 and Honors) could actually be higher odds ratios. For non-PLTW students at PLTW schools (185.90) and non-PLTW school students (270.50) percent of the population with a bachelor's degree or above were also the highest odd ratios.

However their confidence intervals mean that they are for sure the variables with the highest odd ratio for these groups.

Table 4.26 *Variables Predicting Persistence with Bachelor's Degree or Above*

Variable	PLTW School Non-PLTW Students		Non-PLTW Schools		PLTW Students	
Random Coefficient Reliability Est.	Level 1 - .298 Level 2 - .341		Level 1 - .026 Level 2 - .376		Level 1 - .000 Level 2 - .130	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Percent of Population with Bachelor's Degree or Above	<.001	185.90 (30.167, 1145.540)	<.001	270.50 (35.838, 2041.746)	.012	109.76 (2.84, 4241.624)
Percent of Graduates taking SAT	.004	2.96 (1.455, 6.003)	<.001	15.54 (7.307, 33.044)	.156	
Gender	.028	.93 (.869, .992)	.512		.032	.75 (.580, .976)
Non-White Student	<.001	.75 (.669, .850)	.001	.70 (.562, .867)	.084	
Eligible for Free or Reduced Lunch Program	<.001	.75 (.686, .818)	.015	.79 (.648, .955)	<.001	.62 (.500, .773)
Received a Core 40 Diploma	<.001	3.94 (3.446, 4.501)	<.001	3.76 (2.936, 4.811)	<.001	3.00 (2.096, 4.293)
Received an Honors Diploma	<.001	13.58 (11.457, 16.097)	<.001	11.18 (8.469, 14.753)	<.001	9.47 (6.238, 14.397)
8th Grade ISTEP+ Math Score (divided by 100)	.840		.109		.567	
8th Grade ISTEP+ ELA Score (divide by 100)	<.001	1.03 (1.015, 1.039)	.002	1.04 (1.013, 1.060)	.116	

Table 4.27 runs the analysis using the level 3 variable per capita income. Because per capita income is a continuous variable, and has a very wide range, it could be very significant factor in majoring in STEM. The same is true for non-PLTW students at PLTW school and non-PLTW students. As these three tables have shown level three variables are strong predictors of student persistence for all three groups. For PLTW

students, it tends to be proportionally a much larger predictor of persistence, however it is also less precise than the other variables within the model.

Table 4.27 *Variables Predicting Persistence with Per Capita Income*

Variable	PLTW School Non-PLTW Students		Non-PLTW Schools		PLTW Students	
Random Coefficient Reliability Est.	Level 1 - .317 Level 2 - .292		Level 1 - .067 Level 2 - .280		Level 1 - .000 Level 2 - .122	
	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)	p-value	Odds Ratios (Conf Int)
Per Capita Income	<.001	1.000031 (1.000, 1.000)	<.001	1.000038 (1.000, 1.000)	.002	1.000032 (1.000, 1.000)
Percent of Graduates taking SAT	.003	3.01 (1.517, 5.970)	<.001	16.62 (7.624, 36.246)	.129	
Gender	.026	.93 (.868, .991)	.477		.029	.75 (.574, .971)
Non-White Student	<.001	.76 (.678, .863)	.002	.71 (.569, .879)	.076	
Eligible for Free or Reduced Lunch Program	<.001	.75 (.690, .823)	.020	.79 (.655, .965)	<.001	.63 (.507, .788)
Received a Core 40 Diploma	<.001	3.94 (3.444, 4.513)	<.001	3.78 (2.943, 4.844)	<.001	2.99 (2.083, 4.278)
Received an Honors Diploma	<.001	13.61 (11.463, 16.154)	<.001	11.24 8.472, 14.906)	<.001	9.51 (6.244, 14.495)
8th Grade ISTEP+ Math Score (divided by 100)	.802		.096		.552	
8th Grade ISTEP+ ELA Score (divide by 100)	<.001	1.03 (1.016, 1.039)	.002	1.04 (1.013, 1.061)	.122	

For persistence, as with majoring in STEM, there were a lot of similarities between the three groups of students. However, there were also several significant differences. ISTEP+ ELA scores, being white, and the percent of the graduates taking the SAT were significant factors in predicting persistence for both non-PLTW student groups but not for the PLTW students. Being a male (Gender) was not a significant variable for non-PLTW school students but was significant for both PLTW school groups.

CHAPTER 5. DISCUSSION, CONCLUSIONS, RECOMMENDATIONS

5.1 Discussion

5.1.1 Majoring in STEM

Attributes of the community, as part of the IAD framework (See Figure 5.1), can have a significant impact on the outcomes from an action situation. This is certainly true in the role that the attributes of the community play in students across Indiana majoring in STEM. The percent of the population with a high school diploma and above or bachelor’s degree and above (education level of a community) are each significant predictors in both the adoption of PLTW by a school and the future probability of the students majoring in STEM. While community level factors impact all students majoring in STEM, they appear to have a greater effect on PLTW students. This might be because PLTW experiences provide students with a better vision of being a STEM major, and the PLTW students who come from a family with greater educational attainment may feel better supported in pursuing a STEM degree.

PLTW students also have different factors that impact the likelihood they will major in STEM when compared to non-PLTW students. For example, being female is not a negative predictor of majoring in STEM for PLTW students. Also non-white students in PLTW are more likely to major in STEM than white PLTW students. These students’

PLTW experiences may empower them by providing them with the confidence and experience to believe they can succeed in STEM majors predominantly associated with white and Asian males.

When looking at whether PLTW influences students in selecting a STEM major, the data were not initially transparent. Students who attended a PLTW school were significantly more likely to major in STEM than students at a non-PLTW school (odds ratio=1.28) until controlling for whether a student was in PLTW. When the model controlled for PLTW students, attending a PLTW school was no longer statistically significant. Instead being a PLTW student ($p<.001$, odds ratio=4.66) was significant. When comparing PLTW students, non-PLTW students at PLTW schools, and students at non-PLTW schools, there was no statistical difference between the two non-PLTW groups. This suggests the influence of PLTW on the non-PLTW students at the school is minimal.

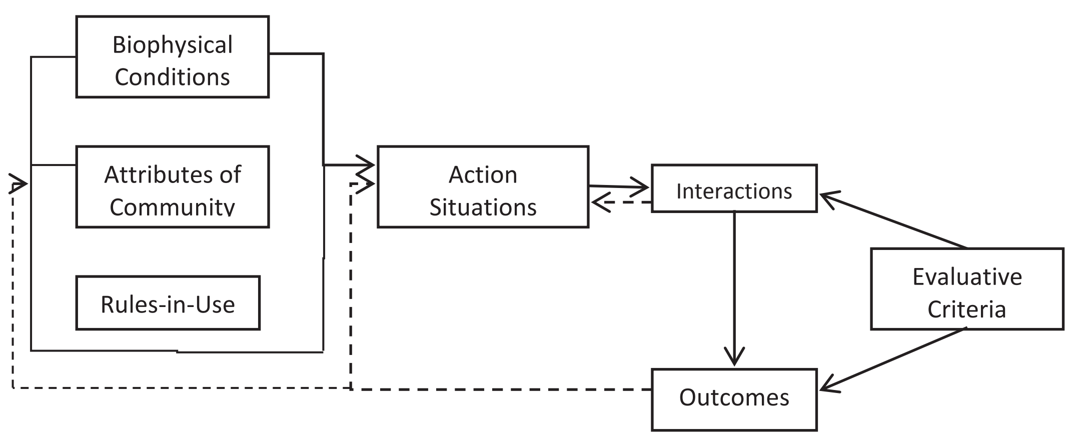

Figure 5.1 The Institutional Analysis and Development Framework

Source: Ostrom (2011)

Further, PLTW students were more likely to major in STEM compared to either of the non-PLTW student groups. This finding is supported by other research done on these same data (Pike & Robbins, 2014) using a direct comparison to a like group of students selected through propensity score matching. PLTW students make up less than 10% of their school population, but enough of them majored in STEM to make the overall STEM major percentages for the entire school different from that of the students at the non-PLTW schools. While PLTW first appears to impact the likelihood of all PLTW school students majoring in STEM, in actuality it did not. As a result of this, school administrators should encourage current PLTW teachers who also teach non-PLTW courses to model these non-PLTW courses after their PLTW course. Administrators should also consider helping other STEM subject area teachers implement more student centered, project-based or inquiry learning modeled after successful PLTW teachers in their school. Additionally, PLTW could evaluate ways to support teachers implementing their materials in implementing similar instructional strategies in other courses.

When looking at the factors that impact a student majoring in STEM, it becomes apparent that PLTW does influence its own students but does not influence the student body as a whole. Variables predicting majoring in STEM for students at PLTW schools and non-PLTW schools are almost identical, with variation in only one variable. In two of the three models, free and reduced lunch is a negative predictor for majoring in STEM for PLTW school students but not for non-PLTW school students. This may be because non-PLTW schools (20.8%) have a lower percentage of free and reduced lunch eligible students than PLTW schools (26.5%). These PLTW students who are eligible for free and reduced lunch may be directly entering the STEM workforce after high school. PLTW school administrators and teachers should be aware of the pathways these students are taking and make sure, if they are interested in post-secondary education that they are aware of the many different ways to fund this education.

However, there are several significant differences when comparing the STEM predictor variables of the two school groups with PLTW students. Gender (being male) was a significant predictor for majoring in STEM for PLTW schools ($p<.001$) and non-PLTW schools ($p<.001$) but not for PLTW students. Females who took PLTW courses are statistically as likely to major in STEM as boys in PLTW. The same cannot be said for non-PLTW students. This suggests that PLTW courses attract and/or encourage both females and non-white students to major in STEM.

Regarding free and reduced lunch eligibility, PLTW students align similarly to their school peers in that being eligible for the free and reduced lunch program decreases the likelihood of majoring in STEM (OR=.79). ISTEP+ ELA score is a negative predictor of majoring in STEM for students at PLTW schools and non-PLTW schools but is not a predictor for PLTW students. These findings imply that taking PLTW has a significant impact on the probability of multiple underrepresented populations (females and non-whites) majoring in STEM but not for the PLTW school as a whole. Therefore, leadership and teachers at PLTW schools should continue to actively recruit underrepresented students with an interest in STEM education into PLTW courses or other STEM courses that will promote their interest in majoring in STEM and provide them with real life hands on learning opportunities.

Socio-economic factors play a significant role in predicting if a PLTW student, and all Indiana students, will major in STEM. However, education level factors (percent of population with a high school diploma/Bachelor's and above) for PLTW had a much smaller predicted odds ratio than for the two non-PLTW groups. This suggests that PLTW may help overcome some community level factors related to education that affect a student decision to major in STEM. When controlling for level 1 and 2 variables community education levels and per capita income have the largest odds ratios of all factors for each of the three student groups. However, the odds ratios of these factors are proportionally larger for PLTW students than for the two non-PLTW student groups. It is not advisable to make a direct comparison between the odds ratios of different multi-level models. However, in these models there are large differences in the odds ratio and the confidence intervals between the models for students who took PLTW courses, students at schools who offer PLTW but did not take a PLTW course, and students attending a school that did not offer PLTW for the percent of the population with a high school degree and above and the percent of the population with a bachelor degree and above. These findings suggest that these two variables have a larger effect on PLTW students than non-PLTW students. Teachers, administrators, policymakers, and PLTW should take this finding into careful consideration as helping students who may come from a less educated background or live in a less educated area may need greater support structures to help them pursue post-secondary education. It is possible that these students have opted to go directly into the workforce, in which case school leadership should make sure these students have been given a clear understanding of pathways they can take into post-secondary education should they so choose later in their life or while they are working.

5.1.2 Persistence

Other research on these data have shown that, when compared to a like group of students, PLTW students are more likely to persist from their freshman to sophomore year of higher education (Pike & Robbins, 2014). However, in this research, when comparing persistence rates for students attending a PLTW school and students attending a school that did not offer PLTW, there was no difference. This suggests that any gains in the persistence of PLTW students were not large enough to impact the overall school level data.

As with majoring in STEM, the factors impacting persistence are very similar between students at PLTW schools and non-PLTW schools. The only difference was that females at PLTW schools were more likely to persist than boys while gender was not a predictor for students at non-PLTW schools. However for PLTW students, the percentage of graduates at the school taking the SAT, being a non-white student, and 8th grade ISTEP+ ELA scores were not predictors of persistence. Since being non-white is a negative predictor of persistence in non-PLTW students but not for PLTW students, it seems that either taking a PLTW course increases the likelihood of non-white students persisting or PLTW courses are attracting non-white students who are already more likely to persist. Additionally, attending a school that has a higher percentage of students considering post-secondary education (percent taking SAT) impacts students who did not take a PLTW course but not those who did. ISTEP+ ELA scores do not impact PLTW students' likelihood to persist but do impact non-PLTW students. Explanations for these differences include that PLTW students may be better prepared for post-secondary education and/or may have a better understanding of their post-secondary major due to their experiences in PLTW. They may also receive more encouragement to seek and succeed in post-secondary education than students who did not take PTLW courses. These findings should stress to school leadership the importance of challenging students in high school as this appears to help them persist not only in high school but in post-secondary education.

5.2 Conclusions

These results imply that PLTW had a statistically significant impact on the students participating in the program excluding students who were eligible for free and reduced lunch. However, this impact does not appear to carry over to the rest of the student body that does not participate in PLTW. One assumes the impact from PLTW occurs because of the PLTW curriculum and/or instructional practices. If this is the case, it appears that neither the curriculum nor instructional practices are positively impacting the instruction of other teachers in the school. Potentially, this impact is not even reaching into non-PLTW courses being taught by the PLTW teachers. As stated earlier, this is important for not only school leaders but PLTW as well. Careful reflection should be given as to why many PLTW teachers are potentially not creating the same learning environments in non-PLTW courses they are teaching. While they may see the effectiveness of this teaching style in their PLTW course(s) why are they not carrying this to their other courses?

Attributes of the community have a significant impact on schools adopting PLTW and the likelihood of students majoring in STEM. This is not surprising. Schools whose students are performing better academically are better positioned to adopt and implement new programs. This, then, could also explain why schools with a lower percentage of non-white students are more likely to adopt PLTW as this variable is strongly correlated with graduation rates. Additionally, the data suggest that PLTW may have a positive impact on some underrepresented populations such as females and non-white students but a negative impact on students who are eligible for the free and reduced lunch program. Sadly, schools with a larger population of non-white students are less likely to adopt PLTW, suggesting that there is still a significant gap in providing this program to a student population that it may benefit. PLTW was utilized in this research for several reasons. Teachers across the state and country utilize the same curriculum when teaching the same course. Additionally, each of these teachers will have, at a minimum, attended the two week PLTW training before they receive the curriculum. While implementation of any curriculum will never be identical, these factors should allow for a much more consistent implementation of the PLTW courses than a program without training and consistent curriculum. When thinking about the findings of this research, it is important to think of them beyond one STEM program. When looking at the findings for the district and community level factors we see that they play a significant role in a student's decision to major in STEM as well as persisting in STEM. Given any STEM program the policies and support structure put in place must reflect these factors.

When thinking about the results of this research in relationship to the IAD framework (see Figure 5.1), the role the attributes of the community have on the outcomes related to the action situation, be it adopting a program or its implementation, must be taken into consideration in any analysis. Additionally, future applications of the IAD framework in education must also take into consideration the nested structure of the mitigating factors and how they may impact the rules-in-use as well as the actors, positions, their possible choices and consequences from those choices. Many of the mitigating factors within this research have large confidence intervals. Exploring the role of these variables further through the IAD framework will likely lead to explanations that could greatly reduce these mitigating factors and help greatly in policy creation and implementation.

5.3 Recommendations

The Indiana funding policy was successful in getting more students, including females and non-white students, to start their post-secondary education majoring in a STEM field. However, the policy also perpetuated the trend of helping schools that are less in need and already better equipped to support their students. In general, schools with a higher population of non-white students, located in areas with lower levels of community education and with greater poverty are the schools that need the most support. The findings of this research suggest that these were the schools this policy generally did not reach. Future funding policies need to address these attributes of the community and find ways to further encourage non-participating schools to adopt programs such as PLTW. A potential way to do this is through incentives that focus the funding directly to the schools with the students with the highest needs and then expanding out to other schools over time. An example of this type of funding policy is used in Alabama with AMSTI (Alabama Mathematics Science and Technology Institute, 2012) in their elementary mathematics and science education.

Policy makers need to take into consideration the different financial and social constraints at schools when creating policy. Directly recruiting or creating different incentives for the highest need schools could increase the likelihood that these schools will implement the policy/program. Additionally, focus on education above, but not in lieu of, wages may in the long term produce an outcome of a better educated and higher earning populace. PLTW school administrators and policy makers need to put forth greater supports for free and reduced lunch eligible students. These are the primary group of identified students that the PLTW funding policy does not appear to be assisting. Providing more of a support structure for these students could increase their likelihood of persistence and majoring in higher paying STEM majors.

Program vendors, especially PLTW, need to do more to support higher need schools in both adopting as well as implementing their programs. PLTW, as a non-profit, should especially be held to a higher standard in getting their program out to schools with the greatest needs and helping them not only adopt, but successfully implement. The face of the state and country are changing. If we are to build the diverse STEM workforce that is needed both policy makers and curriculum providers must take into consideration the attributes of the community when creating a policy or producing a program. Without doing this, the state of Indiana and the nation will lose the diverse STEM workforce that will only help to build the economy.

5.4 Future Research

This dataset needs to be expanded by continuing to track this class through its first four then six years of college to measure persistence in STEM through graduation, four year and six year graduation rates, as well as overall college persistence. Additional graduating classes should be added to the database to determine if the phenomena found in this analysis are consistent over multiple graduating classes. Additionally, if possible, STEM major rates should be tracked for schools before and after implementing PLTW to determine if there was a significant change. Combined variables should also be introduced into the analysis to better measure the interplay that certain variables may have and should provide a better insight into the interactions of factors.

Once these data are analyzed, a multi-scalar approach should be taken to better understand the workings of PLTW in Indiana. Not only should state level data be examined but school and student level data as well. For example, schools with high and emerging STEM major rates should be investigated. This research should be guided by the IAD framework to further investigate each aspect of the framework to build a better understanding of the action situations around STEM programs such as PLTW and the role the attributes of the community play within these interactions. Additionally, onsite interviews and deeper community analyses should be conducted to understand the differences within individual schools. Also, PLTW students in post-secondary education should be surveyed and/or interviewed to explore the impact of PLTW on their collegiate success and choice of major. As is shown through the confidence intervals of many of the statistically significant variables, there is a great deal of variation this future research should try to explain.

Schools who have recently adopted PLTW and those that have not should be investigated, like the PTLW schools, to better understand the factors and characteristics that have kept them from adoption of the program. Understanding the viewpoint of these schools, and the choices they have made will provide better insight into the understanding of how similar policies can be formulated to reach even more student to whom it may be beneficial. Finally, investigating how, if at all, the influence that PLTW appears to create for much of the participating students can be used to influence the entire student body.

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APPENDIX

APPENDIX

Table A.1 *Correlation Table*

		GraduationRate	IS_Rural	AttendanceRate	GradtookAP	GradPassedAP	GraduatesTakingSAT	AvgCompositeMathandVerbal	Free_Reduced	enroll00	pct_urm	AvgHseSize	AvgFamSize	% owner occupied houses	Median Home Value	% Urban Minority	Per Capita Income	PerBS	PerAssociates	PerAbvHS
GraduationRate	Pearson Correlation	1	-.044	.573**	.210**	.253**	.384**	.408**	-.600**	-.040	-.412**	.186**	-.034	.362**	.380**	-.395**	.384**	.248**	.268**	.252**
	Sig. (2-tailed)		.410	.000	.000	.000	.000	.000	.000	.461	.000	.000	.532	.000	.000	.000	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
IS_Rural	Pearson Correlation	-.044	1	.059	-.208**	-.256**	-.080	-.009	-.005	-.371**	-.396**	-.032	-.181**	.244**	-.314**	-.352**	-.308**	-.390**	-.381**	-.424**
	Sig. (2-tailed)	.410		.274	.000	.000	.137	.863	.922	.000	.000	.553	.001	.000	.000	.000	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
AttendanceRate	Pearson Correlation	.573**	.059	1	.137*	.159**	.438**	.326**	-.455**	-.038	-.240**	.229**	.084	.299**	.256**	-.122*	.191**	.064	.127*	.111*
	Sig. (2-tailed)	.000	.274		.010	.003	.000	.000	.000	.477	.000	.000	.116	.000	.000	.023	.000	.237	.018	.039
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
GradtookAP	Pearson Correlation	.210**	-.208**	.137*	1	.685**	.363**	.350**	-.281**	.271**	-.062	.141**	.091	.077	.362**	-.020	.360**	.365**	.350**	.312**
	Sig. (2-tailed)	.000	.000	.010		.000	.000	.000	.000	.000	.250	.009	.090	.150	.000	.708	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
GradPassedAP	Pearson Correlation	.253**	-.256**	.159**	.685**	1	.464**	.437**	-.427**	.492**	-.055	.134*	.120*	.016	.595**	-.045	.565**	.587**	.505**	.464**
	Sig. (2-tailed)	.000	.000	.003	.000		.000	.000	.000	.000	.302	.012	.025	.763	.000	.408	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
GraduatesTakingSAT	Pearson Correlation	.384**	-.080	.438**	.363**	.464**	1	.460**	-.442**	.184**	-.146**	.220**	.095	.237**	.481**	-.087	.421**	.351**	.318**	.309**
	Sig. (2-tailed)	.000	.137	.000	.000	.000		.000	.000	.001	.007	.000	.077	.000	.000	.104	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
AvgCompositeMathandVerbal	Pearson Correlation	.408**	-.009	.326**	.350**	.437**	.460**	1	-.554**	.199**	-.377**	.155**	-.057	.320**	.419**	-.345**	.418**	.332**	.322**	.325**
	Sig. (2-tailed)	.000	.863	.000	.000	.000	.000		.000	.000	.000	.004	.287	.000	.000	.000	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
Free_Reduced	Pearson Correlation	-.600**	-.005	-.455**	-.281**	-.427**	-.442**	-.554**	1	-.015	.663**	-.314**	.070	-.622**	-.643**	.579**	-.622**	-.355**	-.425**	-.412**
	Sig. (2-tailed)	.000	.922	.000	.000	.000	.000	.000		.787	.000	.000	.192	.000	.000	.000	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
enroll00	Pearson Correlation	-.040	-.371**	-.038	.271**	.492**	.184**	.199**	-.015	1	.433**	-.052	.158**	-.316**	.360**	.371**	.381**	.588**	.510**	.504**
	Sig. (2-tailed)	.461	.000	.477	.000	.000	.001	.000	.787		.000	.333	.003	.000	.000	.000	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
pct_urm	Pearson Correlation	-.412**	-.396**	-.240**	-.062	-.055	-.146**	-.377**	.663**	.433**	1	-.199**	.266**	-.688**	-.173**	.920**	-.168**	.143**	.064	.107*
	Sig. (2-tailed)	.000	.000	.000	.250	.302	.007	.000	.000	.000		.000	.000	.000	.001	.000	.002	.007	.236	.046
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
AvgHseSize	Pearson Correlation	.186**	-.032	.229**	.141**	.134*	.220**	.155**	-.314**	-.052	-.199**	1	.818**	.526**	.420**	-.136*	.148**	-.070	-.017	-.158**
	Sig. (2-tailed)	.000	.553	.000	.009	.012	.000	.004	.000	.333	.000		.000	.000	.000	.011	.006	.194	.757	.003
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
AvgFamSize	Pearson Correlation	-.034	-.181**	.084	.091	.120*	.095	-.057	.070	.158**	.266**	.818**	1	.020	.244**	.308**	-.046	-.034	-.050	-.193**
	Sig. (2-tailed)	.532	.001	.116	.090	.025	.077	.287	.192	.003	.000	.000		.713	.000	.000	.387	.525	.350	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
% owner occupied houses	Pearson Correlation	.362**	.244**	.299**	.077	.016	.237**	.320**	-.622**	-.316**	-.688**	.526**	.020	1	.356**	-.655**	.347**	-.045	.080	.066
	Sig. (2-tailed)	.000	.000	.000	.150	.763	.000	.000	.000	.000	.000	.000	.713		.000	.000	.000	.399	.138	.218
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
Median Home Value	Pearson Correlation	.380**	-.314**	.256**	.362**	.595**	.481**	.419**	-.643**	.360**	-.173**	.420**	.244**	.356**	1	-.168**	.825**	.658**	.626**	.597**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000		.002	.000	.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
% Urban Minority	Pearson Correlation	-.395**	-.352**	-.122*	-.020	-.045	-.087	-.345**	.579**	.371**	.920**	-.136*	.308**	-.655**	-.168**	1	-.203**	.094	.030	.079
	Sig. (2-tailed)	.000	.000	.023	.708	.408	.104	.000	.000	.000	.000	.011	.000	.000	.002		.000	.079	.575	.142
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
Per Capita Income	Pearson Correlation	.384**	-.308**	.191**	.360**	.565**	.421**	.418**	-.622**	.381**	-.168**	.148**	-.046	.347**	.825**	-.203**	1	.771**	.777**	.792**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.006	.387	.000	.000	.000		.000	.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
PerBS	Pearson Correlation	.248**	-.390**	.064	.365**	.587**	.351**	.332**	-.355**	.588**	.143**	-.070	-.034	-.045	.658**	.094	.771**	1	.822**	.869**
	Sig. (2-tailed)	.000	.000	.237	.000	.000	.000	.000	.000	.000	.007	.194	.525	.399	.000	.079	.000		.000	.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
PerAssociates	Pearson Correlation	.268**	-.381**	.127*	.350**	.505**	.318**	.322**	-.425**	.510**	.064	-.017	-.050	.080	.626**	.030	.777**	.822**	1	.877**
	Sig. (2-tailed)	.000	.000	.018	.000	.000	.000	.000	.000	.000	.236	.757	.350	.138	.000	.575	.000	.000		.000
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348
PerAbvHS	Pearson Correlation	.252**	-.424**	.111*	.312**	.464**	.309**	.325**	-.412**	.504**	.107*	-.158**	-.193**	.066	.597**	.079	.792**	.869**	.877**	1
	Sig. (2-tailed)	.000	.000	.039	.000	.000	.000	.000	.000	.000	.046	.003	.000	.218	.000	.142	.000	.000	.000	
	N	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348	348

VITA

VITA

Brandon H. Sorge

EDUCATION

Doctor of Philosophy in Technology. (2014, December). Purdue University, West Lafayette, Indiana.

Master of Science in Educational Technology. (1997, August). Purdue University, West Lafayette, Indiana.

Bachelor of Science in Mathematics. (1994, December). Purdue University, West Lafayette, Indiana.

CERTIFICATION

Teaching License, Professional Certification in Secondary Mathematics. (Through 2010, June). State of Indiana.

WORK EXPERIENCE

Research Associate, STEM Education Research Institute (2012 – Present). Indiana University Purdue University Indianapolis. Work with a team of researchers in research and evaluation for K-12 education, discipline-based education research, and workforce development. Collaborate with faculty, staff, and parties external to IUPUI on grant proposals and projects. Create measurement systems and evaluations aligned to proposals. Create and manage large datasets for research and evaluation purposes.

Director of Operations, Indiana – Science, Engineering, Technology, and Mathematics Resource Network. (2007 – 2012). Purdue University. Initiated a statewide network with 11 regional lead institutions of higher education to facilitate regional and statewide improvement in K-12 STEM education. Developed a strategic plan aligned with national standards, research on effective STEM education reforms, and state visions for STEM education provided by the Office of the Governor of Indiana and the Indiana Department of Education. Co-convened a committee that created a series of credit courses to address needs in middle level mathematics. Provided leadership during the development of the Indiana Science Initiative that involved 130 schools representing 2,000 teachers and 53,000 students in systemic reform of K-8 science education. Helped to develop a webpage that will be a leading information source to students, parents, teachers, administrators, and higher education personnel in K-12 STEM education. Convened a facilitator committee representing key stakeholders in K-12 STEM education from higher education, K-12 education, business, government, and philanthropic organizations.

Director of Technology. (1996 – 2007). Benton Community School Corporation. Supervised all areas of technology with 3 full time and 7 part time staff members. Developed and oversaw annual technology budget ranging from $400,000 to $1,200,000 to purchase, maintain, and enhance technology for the school system. Worked with teachers and staff to heighten their technology skills, knowledge and ability to integrate technology into their teaching. Collaborated with district staff and administration on grant proposals and projects. Oversaw the maintenance and utilization of student data.

Graduate Instructor. (1996 – 1997). Purdue University. Taught Algebra and Mathematics for elementary education majors. Assisted in incorporating Geometer's Sketchpad into the classroom learning environment using a problem-centered approach.

Secondary Mathematics Teacher. (1994 – 1996). Logansport High School. Taught Geometry, Investigative Geometry, and Pre-Algebra. Implemented multi-room computer network for instructional support.

PUBLICATIONS

Watt, J. X., Feldhaus, C. R., **Sorge, B. H**., Fore, G. A., Gavrin, A. D., & Marrs, K. A. (2014). The effects of implementing recitation activities on success rates in a college calculus course. Journal of the Scholarship of Teaching and Learning, 14(4), 1-17.

Hensel, D. J., & **Sorge, B. H.** (2014). Adolescent Women's Daily Academic Behaviors, Sexual Behaviors, and Sexually Related Emotions. Journal of Adolescent Health.

Little-Wiles, J.M., Fox, P.S., **Feldhaus, C.R.,** Hundley, S., & **Sorge, B.** (2013). Student Engagement Strategies in One Online Engineering and Technology Course. *Proceedings of the 120th ASEE Annual Conference & Exposition,* Atlanta, GA. June 23-26, 2013.

Farahmand, F., Dark, M., Liles, S., & Sorge, B. (2009, August). Risk perceptions of information security: A measurement study. In Computational Science and Engineering, 2009. CSE'09. International Conference on (Vol. 3, pp. 462-469). IEEE.

REPORTS AND SUMMARIES

Sorge, B., Fore, G., & Scheive, M. (2014). Ready NWI Professional Development for teachers of Algebra I Evaluation Report.

Sorge, B., & **Fore, G.** (2014). NUE Evaluation Report.

Sorge, B. H. & Ainsley, P., (2014, August). *Indiana Science Initiative update: Student performance on state accountability testing from ten schools participating school-wide for four years*.

Sorge, B. H. & Walker, W. S., III., (2013, August). *Indiana Science Initiative update: Student performance on state accountability testing from ten schools participating school-wide for three years*.

Walker, W. S., III., & **Sorge, B. H.** (2012, December). *Indiana Science Initiative update: Student performance on state accountability testing from ten schools participating school-wide for two years*. Retrieved from http://www.indianascience.org/advocacy/tenschoolsimpact.pdf.

Walker, W. S., III**.**, Hicks, J. L., & **Sorge, B. H**. (2012, July). *The Indiana Science Initiative: Goals, history, and moving forward*. Unpublished manuscript.

Evaluation Team of the Discovery Learning Research Center, Walker, W. S., III., **Sorge, B. H.**, Hicks, J. L., & Cook, N. D. (2012, January). *Evaluation of the Indiana – Science, Technology, Engineering, & Mathematics Network's science education project*. Retrieved from http://www.indianascience.org/advocacy/pilot.pdf.

Tyminski, A. M., Walker, W. S., III., & **Sorge, B.** H. (2008, March). *Indiana – Science, Technology, Engineering, and Mathematics (I-STEM) Resource Network Middle Level Mathematics Initiative: Evaluation – Fall 2007*. Unpublished manuscript, Purdue University.

UNPUBLISHED WORK

Cook, N. D., **Walker, W. S., III.**, Sorge, B. H., & Weaver, G. C. *The Indiana Science Initiative: Lessons from a classroom observation study*. Manuscript submitted for publication.

Feldhaus, C., Little-Wiles, J., **& Sorge, B.** (2014, Accepted). Conflict Resolution and Ethical Decision Making For Professional Engineers in Large Global Organizations. *Contemporary Ethical Issues in Engineering.*

PROCEEDINGS OF NATIONAL MEETINGS AND SYMPOSIA

Little-Wiles, J.M., Fox, P.S., **Feldhaus, C.R.,** Hundley, S., & **Sorge, B.** (2013). Student Engagement Strategies in One Online Engineering and Technology Course. *Proceedings of the 120th ASEE Annual Conference & Exposition,* Atlanta, GA. June 23-26, 2013.

PROCEEDINGS OF REGIONAL AND STATE MEETINGS AND SYMPOSIA

Fore, G**., Sorge, B. H.**, Feldhaus, C.R., Agawal, M., & Varahramyan, K. (2014, April). *Learning at the Nano-Level: Exploring the Unseen and Accounting for Complexity in How (and Why) Teachers Learn.* Poster session presented at the IUPUI Research Day.

Robbins, K., **Sorge, B.,** Helfenbein, R., & Feldhaus, C. R. (2014, April). *Project Lead the Way: Analysis of Statewide Student Outcomes.* Poster session presented at the IUPUI Research Day.

Scheive, M. Fore, G., & **Sorge, B. H.,** (2014, April). *Understanding the INDA Student Summer Camp Experience.* Poster session presented at the IUPUI Research Day.

Gavrin, A., Fore, G., & **Sorge, B. H.** (2013, April). *Identifying Connections and Potential Synergies among IUPUI STEM Education Initiatives*. Poster session presented at the IUPUI Research Day.

Sorge, B. H., Walker, W. S., III., & Feldhaus, C. R. (2013, April). *Evaluating K-12 STEM education programs in Indiana: The SERI/I-STEM partnership*. Poster session presented at the IUPUI Research Day, Indianapolis, IN.

Walker, W. S., III., Cook, N. D., **Sorge, B. H.,** Hicks, J. L., & Weaver, G. C. (2012, February). *The Indiana Science Initiative [ISI]: Results from a pilot study*. Poster session presented at the Discovery Learning Research Center Showcase and Symposium, West Lafayette, IN.

Walker, W. S., III., & **Sorge, B. H.** (2008, October). *The I-STEM Resource Network*. Poster session presented at the Back to Class Engagement Session, West Lafayette, IN.

INVITED AND PLENARY PRESENTATIONS

Sorge, B. (2013, March 18). *The Lilly Science Coaches: Analysis of the Science Coach and Teacher Surveys.* Presentation at the Lilly Science Coach Meeting, Eli Lilly and Company, Indianapolis, IN.

Sorge, B.H. (2010, December), *Indiana Science Textbook Adoption and the Indiana Science Initiative.* Avon Community Schools Textbook Adoption Committee meeting, Avon, IN.

Sorge, B.H. & Hicks, J. (2010, November), *Indiana Science Textbook Adoption and the Indiana Science Initiative.* Indiana Curriculum and Instruction Association, Plainfield, IN.

Walker, W. S., III. (2010, April). Indiana Science Initiative. Plenary session at the Discovery Learning Research Center's Second Annual PI Summit, West Lafayette, IN.

Sorge, B. H., & Heilman, K.H. (2010, February). *Making the change in Indiana*. Plenary session at the Indiana Science Summit, Indianapolis, IN. (Also see STATE MEETINGS AND CONFERENCES PLANNED OR HOSTED).

Walker, W. S., III., **Sorge, B. H.**, & Hicks, J. L. (2009, November). Science education reform in Indiana. Presentation for the National Science Resources Center's National Advisory Board Meeting, Washington D.C.

Schuler, S. G, Armbrecht, R., Estes, J., **Sorge, B. H.** (2009, February). Public-private partnerships working to improve STEM education. Panel presentation at the Annual Conference on STEM Education Policy of the Triangle Coalition for Science and Technology Education, Washington, D.C.

Walker, W. S., III., **Sorge, B. H**., & Lechtenberg, V. L. (2008, December). I-STEM Resource Network: Promoting K-12 STEM education in Indiana. Presentation for Indiana's Education Roundtable, Indianapolis, IN.

Sorge, B.H., Walker, W.S. III & Staver, J. (2008, March). *The I-STEM Resource Network: Promoting STEM Education.* Presentation at the Annual Conference of the National Catholic Education Association, Indianapolis, IN.

Sorge, B.H., Walker, W.S. III, & Staver, J., (2008, February). *The I-STEM Resource Network: Promoting STEM Education in Indiana.* Presentation at the Annual Conference of the Indiana Charter School Association, Indianapolis, IN.

Sorge, B.H. (2006, November). *Open Source Scanning Tools.* A Call to Action for the Education Community, Fargo, ND.

Sorge, B.H. (2006, November). *Information Security Policy.* . A Call to Action for the Education Community, Fargo, ND.

Sorge, B.H., (1998, March). *The Future of Technology.* Featured Speaker at the Benton County Committee for Academic Excellence, Fowler, IN.

Sorge, B.H., (1996, January). *Using Technology in the Classroom.* Phi Delta Kappa Regional Chapter Meeting, West Lafayette, IN.

REFEREED/JURIED PRESENTATIONS – NATIONAL CONFERENCES

Walker, W. S., III., & **Sorge, B. H.** (2012, October). *The Indiana Science Initiative: Results from a partnership pilot*. Session presented at the National Outreach Scholarship Conference, Tuscaloosa, AL.

Hansen, G., **Sorge, B. H.,** & Hicks, J. (2012, October). *Lilly Science Coaches: Supporting Research-Based Science Instruction*. Session presented at the National Outreach Scholarship Conference, Tuscaloosa, AL.

Sorge, B. H., Wilkins, M. & Hansen, G. (2012, October). *The Indiana Science Initiative: Utilizing University Materials, Management, and Distribution*. Session presented at the National Outreach Scholarship Conference, Tuscaloosa, AL.

Sorge, B. H., Hicks, J. (2012, February) *Systemic Change in Science Education – It Really Does Take a Village.* Session presented at the Mathematics and Science Partnership Program Conference, New Orleans, LA.

Walker, W. S., III., & **Sorge, B. H.** (2009, September). *The I-STEM Resource Network: Promoting K-12 STEM education in Indiana*. Session presented at the Annual Meeting of the Outreach Scholarship Conference, Athens, GA.

Sorge, B. H., Walker, W. S., III., & Hicks, J. L. (2009, September). *Partnerships with educational impact: Reforming science education in Indiana*. Session presented at the Annual Meeting of the Outreach Scholarship Conference, Athens, GA.

REFEREED/JURIED PRESENTATIONS – REGIONAL/STATE CONFERENCES

Hicks, J. L., Kruse, J., Fields, J., Miller, M. & **Sorge, B. H**., (2013, February). The *Indiana Science Initiative and Its Effect on the Classroom*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Hicks, J. L., **Sorge, B. H**., Hansen, G., Walker, W. S., III**.** (2013, February). *Indiana Science Initiative*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Hicks, J. L., **Sorge, B. H**., Hansen, G., Walker, W. S., III**.** (2012, February). *Indiana Science Initiative*. Session presented at the Annual Conference of the Hoosier Association of Science Teachers Inc., Indianapolis, IN.

Walker, W. S., III., & **Sorge, B. H.** (2009, October). *The Indiana STEM Resource Network*. Session presented at the Annual Conference of the Engineering/Technology Educators of Indiana, Indianapolis, IN.

Walker, W. S., III., **Sorge, B. H**., & Hicks, J. L. (2009, January). *The Indiana Science, Technology, Engineering, Mathematics (I-STEM) Resource Network: Promoting STEM education in Indiana*. Session presented at the Winter Conference of the Indiana Principals Leadership Academy, Indianapolis, IN.

Walker, W. S., III., & **Sorge, B. H.** (2008, October). *The I-STEM Resource Network: Resources and information for K-12 teachers of mathematics*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Sorge, B. H., & Walker, W. S., III. (2008, September). *The I-STEM Resource Network*. Session presented at the State Conference of the Indiana Association for Career and Technical Education, Indianapolis, IN.

Sorge, B.H. (2008, April). *The I-STEM Resource Network: Promoting STEM Education in Indiana.* Indiana-Illinois Regional Conference for the American Society for Engineering Education. Terre Haute, IN.

Walker, W. S., III., & **Sorge, B. H.** (2007, November). *The I-STEM Resource Network: Promoting STEM education in Indiana*. Panel presentation at the Indiana's Future Conference: Equity, Engagement & Education for Economic Success, Indianapolis, IN.

Walker, W. S., III., & **Sorge, B. H.** (2007, October). *The I-STEM resource network: Promoting STEM education in Indiana*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Sorge, D. H., **Sorge, B. H.**, & Walker, W. S., III. (2000, November). *"Standard"izing technology integration: Strategies that work*. Session presented at the Annual Conference of the Indiana Council of Teachers of Mathematics, Indianapolis, IN.

Sorge, D.H., & **Sorge, B.H.,** Mandell, S. (1996, November). *From Wagon Wheels to Space Ships.* National Council of Teachers of Mathematics Annual Conference, South Bend, IN.

Sorge, D.H., & **Sorge, B.H.**, (1994, October). *Applications of Computers in the Mathematics Classroom.* Indiana Council of Teachers of Mathematics Annual Conference, Indianapolis, IN.

GRANTS RECEIVED

Evaluation of the Innovate NW Indiana MSP Grant, (2014-2105) PI: **Sorge, B. H.** Co-PI: Fore, G. A., & Feldhaus, C. R. College Acceleration Network, $16,000.

Evaluation of the CTU 4 CSE MSP Grant, (2014-2015) PI: **Sorge, B. H.** Co-PI: Fore, G. A., & Feldhaus, C. R. Lafayette School Corporation, $15,000

Evaluation of the SEGS Teacher Quality Grant, (2014-2015) PI: **Sorge, B. H.** Co-PI: Fore, G. A., & Feldhaus, C. R. Purdue University, $14,000.

Evaluation of the Indiana Work Place Specialist I Training Program Revisions, (2014-2015) PI: **Sorge, B. H.** Co-PI: Fore, G. A., Indiana Association of Career and Technical Education Directors, $15,000

Establishing an Evaluation System for US2020 Mentoring in Indianapolis, (2014-2015) PI: **Sorge, B. H.** Co-PI: Fore, G. A., & Feldhaus, C. R. Techpoint Foundation for Youth, $16,000.

Evaluation of the Indiana Science Initiative, (2014-2105) PI: **Sorge, B. H.** Co-PI: Fore, G. A., & Feldhaus, C. R. Purdue University, $84,136.

STEMCorp Research Team: Increasing Diversity and Participation In High School Stem Education, (2014-2015) PI: Ward, R., Co-PI: Agarwal, M., Rubens, E., & **Sorge, B. H**. IUPUI Venture Fund, $38,100.

Conceptualizing Project Lead the Way for Adult Education, (2014-2015) PI: Feldhaus, C. R., Co-PI:Buckwalter, J., **Sorge, B. H.,** & Covault, J. Indianapolis Private Industry Council, $69,000.

Evaluation of the ReadyNWI Grant, (2013-2104). PI: **Sorge, B. H.** Co-PI: Fore, G**.** College Acceleration Network, $16,500.

The Indiana Science, Technology, Engineering, and Mathematics (I-STEM) Resource Network. (2012 – 2013). PI: Lechtenberg, V. L. Co-PI: Walker, W. S., III., & **Sorge, B. H**. Central Indiana Corporate Partnership, $1,530,000.

Literacy enriched science through guided inquiry: Elevating thinking and knowledge. (2011 – 2013). PI: **Sorge, B. H**. Co-PI: Walker, W. S., III., & Staver, J. R. Indiana Department of Education, $1,898,984.

Indiana Science Initiative multi-user database. (2011 – 2012) PI: Walker, W. S., III**.** Co-PI: **Sorge, B. H.** Eli Lilly & Company Foundation, $120,000.

Indiana Department of Education, Title II. (2011). PI: **Sorge, B. H.** Co-PI: Walker, W. S., III. Indiana Department of Education, $375,000.

I-STEM Resource Network/Indiana Science Initiative. (2010 – 2016). PI: **Sorge, B. H**., Co-PI: Walker, W. S., III. Eli Lilly & Company Foundation, $1,500,000.

Indiana Department of Education, Title II. (2010). PI: **Sorge, B. H.** Co-PI: Walker, W. S., III**.** Indiana Department of Education, $375,000.

I-STEM K-5 science program. (2010). PI: **Sorge, B. H**. Co-PI: Walker, W. S., III**.,** Indiana Department of Education, $148,310.

Indiana modeling workshops. (2010). PI: **Sorge, B. H**., Co-PI: Walker, W. S., III., Indiana Department of Education, $173,660.

The I-STEM Resource Network. (2009 – 2011). PI: Lechtenberg, V. L., Co-PI: Walker, W. S., III., & **Sorge, B. H**. Central Indiana Corporate Partnership Foundation (Lilly Endowment), $2,000,000.

I-STEM Resource Network operations. (2009 – 2010). PI: Walker, W. S., III., Co-PI: Lechtenberg, V. L., & **Sorge, B. H.** Indiana Department of Education, $500,000.

Indiana Science Summit. (2009). PI: **Sorge, B. H**., Co-PI: Walker, W. S., III. Eli Lilly & Company Foundation, $35,000.

I-STEM professional development grants. (2009). PI: Walker, W. S., III., Co-PI: Lechtenberg, V. L., & **Sorge, B. H.** Indiana Department of Education, $299,573.

Indiana Algebra Readiness Initiative. (2009). PI: Walker, W. S., III., Co-PI: **Sorge, B. H**. Indiana Department of Education, $49,952.

Indiana science and mathematics initiatives. (2009). PI: **Sorge, B. H.** Co-PI: Walker, W. S., III. Indiana Department of Education, $64,000.

Grade Report. (2008 – 2009). PI: S**orge, B. H**. Co-PI: Lechtenberg, V. L., & Walker, W. S., III**.** BioCrossroads/Lumina, $200,000.

Indiana science strategic plan. (2008). PI: Walker, W. S., III. Co-PI: Lechtenberg, V. L., & **Sorge, B. H**. Central Indiana Corporate Partnership, $25,000.

Indiana mathematics. (2008). PI: Walker, W. S., III., Co-PI: Brown, C. A., & **Sorge, B. H.** Indiana Department of Education, $299,573.

Indiana Algebra Readiness Initiative. (2008). PI: Walker, W. S., III., Co-PI: Brown, C. A., & **Sorge, B. H.** Indiana Department of Education, $249,791.

Middle Level Mathematics Initiative. (2007). PI: Walker, W. S., III**.** Co-PI: Lechtenberg, V. L., & **Sorge, B. H**. National Governor's Association, $220,000.

I-STEM communications and promotions. (2007). PI: Walker, W. S., III. Co-PI: Lechtenberg, V. L., & Sorge, B. H. National Governor's Association, $100,000.

Indiana High School Grade Report. (2007). PI: Walker, W. S., III. Co-PI: Lechtenberg, V. L., & **Sorge, B. H**. National Governor's Association, $80,000.

AWARDS

Seeds for Success Award. (2012). Award recognizing principal investigators and co-investigators garnering $1 million or more in grants.

Seeds for Success Award. (2011). Award recognizing principal investigators and co-investigators garnering $1 million or more in grants

Seeds for Success Award. (2010). Award recognizing principal investigators and co-investigators garnering $1 million or more in grants.

STATE MEETINGS AND CONFERENCES PLANNED OR HOSTED

Indiana Primary Algebra Readiness Initiative. (2010, Summer and Fall). Statewide workshops supported by the I-STEM Resource Network with the Indiana Department of Education to prepare teachers to address problem solving, cognitive demand, generalization, number sense, relationships, operations, patterns, and functions.

Indiana Science Summit. (2010, February). Conference co-planned and supported by the I-STEM Resource Network with the Indiana Department of Education and Eli Lilly and Company to gain support for and to help progress the Indiana Strategic Plan for Science Education Reform. Attendees included 250 leaders from K-12 education, higher education, government, and not-for-profits. Indianapolis, IN.

Indiana Building Awareness for Science Education Symposium. (2009, October). Conference planned and hosted by the I-STEM Resource Network to build awareness for the need of reform in science education in Indiana. Attendees included 150 K-12 administrators, K-12 educators, business members, government officials, employees of not-for-profits, and higher education faculty and administrators. South Bend, IN.

Indiana Algebra Readiness Workshops. (2008, Summer). Workshops developed and organized by the I-STEM Resource Network included activities and information for teachers to address Cognitive Demand, Algebraic Habits of Mind, and Formative Assessment in their classrooms. Attended by 160 middle school mathematics teachers and Algebra I teachers. Indianapolis, IN; Evansville, IN; Fort Wayne, IN; and Merrillville, IN.

Indiana Algebra Readiness Conference. (2008, June). Conference co-developed and co-hosted by the I-STEM Resource Network for working with students potentially at risk of failing Algebra I and the Core 40 Algebra I End-of-Course Assessment. Attended by 200 middle school mathematics teachers, Algebra I teachers, and administrators. Indianapolis, IN.

Indiana Building Awareness for Science Education Symposium. (2008, April). Conference co-planned and hosted by the I-STEM Resource Network to build awareness for the need of reform in science education in Indiana. Attendees included 150 K-12 administrators, K-12 educators, business members, government officials, employees of not-for-profits, and higher education faculty and administrators. Indianapolis, IN.

PROFESSIONAL AFFILIATIONS

National Council of Teachers of Mathematics. (Member since 1993).

Indiana Council of Teachers of Mathematics. (Member since 1994).

Phi Delta Kappa. (Member 1994 - 2006).

Chapter Secretary and Webmaster, 2004 to 2006.

Triangle Coalition for Science and Technology Education.

SERVICE: COMMITTEES

Indiana STEM Action Coalition. (2012-Prensent).

Indiana Girls Collaborative Project – Champions Board Member. (2010-Present).

Indiana Afterschool Network STEM Advisory Board. (2011-Present)

Indiana Afterschool Network STEM Assessment and Evaluation Committee – Chair. (2012-Present).